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Diagnostics of cone crusher feed segregation using power draw measurements

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ABSTRACT

In comminution processes, the equipment normally operates at non-optimal conditions and due to poor access to crushers and deficient monitoring of them, this information is not acquired. Cone crushers have a crushing chamber that is revolved around its centre axis and crushing does not occur all at once but in a circular motion. This property gives rise to a potential non-optimal crushing in the form of power draw fluctuations due to the variance in feed across the crushing chamber with respect to e.g. mass flow, particle size distribution and other material properties. Studies have shown that a high rate of the power draw measurement provides the ability to expose a feeding miss-alignment. This paper shows how changes in the operation of the crusher, due to differences in feed material properties as a segregation, can be diagnosed and determined for future comminution process improvements.

1. Introduction

Compressive crushing is energy efficient as a consequence of the crushing principle and the imposed stress-state, in comparison to other principles not conditioned by form (Schönert, 1972). Therefore it is desirable to find ways forward for high utilisation and production performance of compressive crushers without increasing the production and maintenance costs. The compressive pressure and thus the internal loads and stresses can vary significantly during operation because of the mechanical design and behaviour of the crusher even if the machine settings are kept constant. This phenomenon is explained by density variations of the particle beds in the crusher cavity which in turn originates from particle segregation and feeding alignment (Quist, 2017; Evertsson et al., 2016).

Cone crusher mantles are mounted on the main shaft which rests in an eccentric bushing, creating an angle between the main shaft and the mantle centre axis pictured in Fig. 1. This enables the nutation and rotational motion of the mantle that generates the compressive action in the crushing chamber. Due to the nutation and the rotational motion of the mantle the particles that are trapped in the crushing chamber results in a force acting on the mantle. The force distribution translates into a torque, due to the eccentric offset of the main shaft where the mantle is supported. The torque is transferred to the driveshaft, through a belt drive to the motor. By measuring the power drawn by the motor, the change in force acting on the mantle over time can be estimated. If the power draw sampling rate is high enough, the variations over every crusher revolution can be investigated and used for operating diagnostics (Gröndahl et al., 2017).

In crushing processes the crushers are closed off from the surroundings for safety and contamination purposes. Therefore, the state of operation of the crusher is visually concealed and other methods for process diagnostics has to be implemented. Power draw measurement is a suitable method due to its installation being nonintrusive, the required investment resources are low and the measurement is sufficiently accurate.

The crusher operation can be affected by multiple factors such as a miss-aligned feed, feed segregation and stiffness and shape of the material. The purpose of this study is to diagnose a feed segregation as detection of a miss-aligned feed has already been established using power draw sampling (Gröndahl et al., 2017).

1.1. Segregation

Segregation is a phenomenon that refers to the change in attributes of the processed material across the geometric position e.g. in a crusher or on a belt feeder. The attributes that vary in comminution processes are often the Particle Size Distribution (PSD) or the mechanical properties of the material.

The cause of segregation when referring to a difference in particle size is granular convection. In a volume of different sized particles, the

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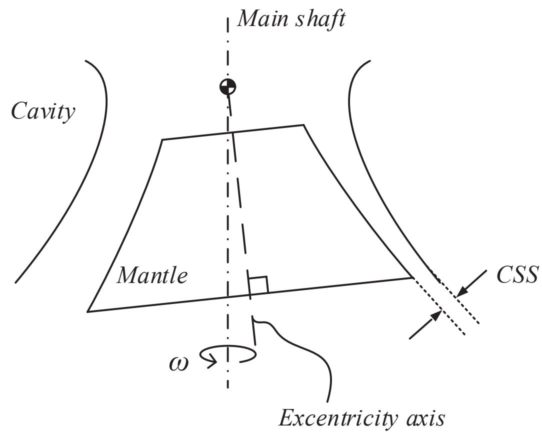

Fig 1. Schematics of the principle of a cone crusher.

smaller fall to the bottom, causing the larger to rise up, when subject to vibrations or similar excitations (Knight et al., 1996). In a process, different sources of the feed can also result in segregation due to the inherent material differences. In a mine or a quarry, the materials can have a significant difference locally. The ore type in itself can also vary even when mining for the same mineral (Moskalyk & Alfantazi, 2003). As the feed is transported on belts, the granular convection starts and when the feed falls off the belt onto another belt or into a crusher hopper, the different sized particles will tend to gather in different areas of the geometry. This causes, among other things, segregation in cone crusher feeds.

Any change to the material in the feed of the crusher has an impact on the energy required and its variance. A wider PSD will give a higher bulk density during inter-particle breakage, thus, increasing the mean required power draw. Bigger and fewer particles will affect the variance in the power draw since the energy required for breakage pulsates with every particle, in comparison to a higher number of smaller particles resulting in an evener power draw. Material properties, such as stiffness, will affect the power draw intuitively. It has been shown that any variance in the power draw is disadvantageous (Gröndahl et al., 2017), meaning that segregation needs to be diagnosed and rectified in order to improve the comminution process.

To solve the problem with segregation, the feed can be mixed in various ways (Quist & Evertsson, 2010). In the event of a segregation that acts as a feeding miss-alignment, due to a wider PSD on one side of the crusher increasing power draw locally, the method of moving the feed can be implemented. These solutions are fairly well known but the key to solving the issues is to find the segregation problem and to pinpoint the characteristics of it, in order to know what solution that is appropriate to incorporate.

2. Method

To investigate how segregation in a cone crusher affects the power draw, a feed with a controlled segregation was created. The chosen method for creating this difference was to use two completely different materials, both by PSD and by composition. Since segregation in itself can depend on many factors, the used materials needed to be different by any means and not necessarily only in PSD or composition.

The crusher used was a lab scale cone crusher of the model Morgårdshammar B90. A belt feeder was used to feed the crusher, Fig. 2. The two different materials were fed into the crusher still separated, creating a difference in the feed throughout the crushing chamber, thus creating one distinctly segregated feed.

A divider plate was put into the feeder hopper containing the materials which were then pulled out on each side of the belt, creating one feed that was divided by the middle, shown in Fig. 3A. To keep the materials separated while using the belt feeder, a funnel for directing the two materials, was designed, Fig. 3B. The purpose of it was to divide the feed coming off of the belt feeder and direct both materials to opposite sides of the crushing chamber inlet. The resulting feed was an even flow throughout the crushing chamber, but with different materials on either side.

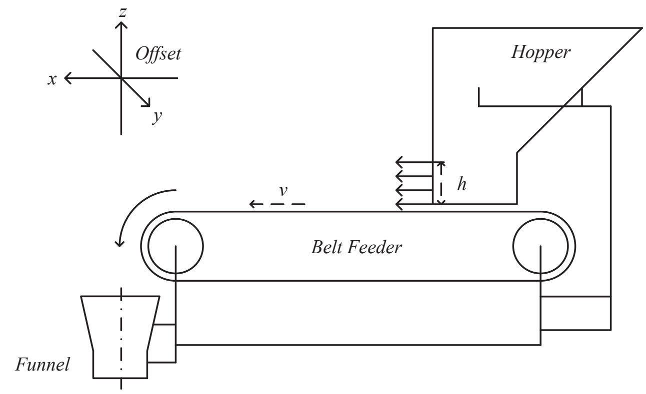

Fig. 2. Belt feeder schematics.

As the segregated feed was crushed, the power draw was sampled at a rate of 10 kHz with a resolution of 24 bits. The speed of the crusher was 600 RPM or 10 Hz and thus, 1000 samples were made for every crusher revolution giving an angular resolution of 0.36 degrees.

3. Results

In Fig. 4, the power draw from two individual tests of crushing the two materials are shown. The length of them are different and the respective side of the materials in the hopper have been switched, whereas every other setting was retained. The constructed funnel for feeding the two materials into the crusher could have left a slight longitudinal velocity to the flow if not operating as intended. The only difference that could occur due to this would be a higher feeding flow in the front or the back of the crushing chamber. When switching the sides for the materials, this slight feeding miss-alignment would react differently, if the concentration were to occur where going from one material to the other or vice versa. In the power draw data, there are no clear indications of this kind of abnormality, but there were slight differences between the tests. In general, the two tests were conducted under the same conditions or with negligible differences.

To more closely see how the power draw varies throughout crushing, a section of 0.5 s or 5 crusher revolutions starting 10 s into the tests are shown in Fig. 5. These sections were arbitrarily chosen at the same point in time for both tests. Both plots show the mean of the power draw taken over the entire test. In Fig. 5B, the power draw seems to vary between two main levels. However, looking at the entire sample in Fig. 4B, the peaks tend to have a significantly higher amplitude than the amplitude of the low points, suggesting that the higher level is more fluctuating than the lower one. For Fig. 5A, a conclusion is harder to give from the power draw alone since it does not show any clear pattern. The signal in Fig. 4A is smoother than Fig. 4B even though the peaks are higher than the low points are low. This is logical though since a concentration of particles can come at the same time increasing the power draw.

In Fig. 6, the histogram and the cumulative distribution function of both tests are shown. This plot shows a significant difference between the tests as test B is skewed in a probability density distribution whereas test A is close to a normal distribution. Fitting gamma distribution to the two test cases gave k and θ values at 25.46 and 54.22 for test A and values 16.91 and 83.34 for test case B. This results in skewness values at 0.40 and 0.49 for case A resp. case B. This suggests that something in the feed flow between the tests made a difference. The skewness of test