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Research Paper

Modification of Design of Feed Chute in A Tertiary Cone Crusher at the Sarcheshmeh Copper Complex

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Abstract: Comminution is the most energy intensive operation which constitutes the major portion of operating and capital costs of the mineral processing plants. Working at the maximum operating capacity of comminution equipment plays a significant role in the efficiency of the circuit. Also, due to the effect of crusher efficiency on the downstream circuit performance, optimization of the crushing circuits has received considerable attention. In this research, the effect of feed chute design on tertiary cone crusher performance at the Sarcheshmeh copper complex was studied. A close monitoring of the performance crusher revealed that main problems were high fluctuations of power draw and uneven and high-rate wear of crusher liners. Such pitfalls were clear evidences of an improper feeding arrangement into the crusher. Accordingly, various feed chute designs were employed in the simulations by an in-house developed DEM software called KMPCDEM© to find more uniform feed distribution on the distribution plate of the crusher. Results showed that by changing the shape of feed chute from cubic to cylindrical, decreasing its surface area from 0.34 to 0.24 m2 and increasing the cylinder length above and below the feed chute plate from 0 to 45 cm and from 53 to 95 cm, respectively, uniform feed distribution was obtained. After installing the new feed chute design in the plant, a detail monitoring over a period of 15 months showed a reduction of the standard deviation of crusher power draw from 13 to 3 kW. A better crusher control caused choke feeding. Therefore, 36% increase in the crusher throughput and finer and narrower product size distribution occurred. Furthermore, the life of crusher liners increased from 8 months to 15 months on account of more

uniform and lower rate of wear on mantle and liners.

Keywords: Open Pit Mine, Ultimate Pit Limit, Optimization, Heuristic algorithm.

INTRODUCTION

Comminution circuits (including crushing and grinding) form a vital part of the minerals processing industry and consume large quantities of energy (i.e., approximately 2% of electricity consumed on a national level). Cone crushers utilize compressive mechanism and are the most commonly crusher type used in minerals processing circuits for secondary and tertiary crushing [1]. Typically, the main objective of crushing circuits is to maximize the crushing throughput at some specified product size by maintaining the highest possible crusher power draw. High fluctuations of power draw sound the alarm, meaning that the crusher is suffering from the incorrect operating conditions. Accordingly, the power draw variance is equally important as its absolute value. A number of variables could affect power draw such as ore feed stiffness and size, ore feed rate, closed side setting (CSS), and feeding mode. Generally, ore stiffness and, in some cases, feed size are not controllable and the feed rate usually depends on the upstream and downstream operations. The closed side setting of a cone crusher is the most well-known adjustable mechanical parameter. In practice, the feeding mode (feed presentation; the manner in which crusher is fed) is the parameter which could have a significant effect on the performance and deserves special attention. Under the shadow of choke feeding importance, feed presentation is often neglected in plants and has been regarded as a part of normal operation and not very detrimental to crusher performance. However, Evertsson [2] showed poor distribution of feed is not simply a minor problem, but is a cause of high variation in crushing forces and inefficiency of the process. Nevertheless, it has been reported that when operating under full choked feeding condition, the bad feeding presentation is no longer a major problem [3], Bearman et. al. [4] showed that in a cone crusher appeared to be fully choke fed, the poor distributed feed led to drawbacks in crusher performance. Discrete element method (DEM) is a computational technique to simulate the particle flow in various types of equipment. The objective of present work was to investigate the effect of feeding arrangement on the performance of the tertiary crusher through finding an optimal design for the feed chute. The approach started with developing the DEM codes for multi-geometry simulation in order to simulate the overall crushing circuit with sufficient resolution. DEM simulations with various feed chute designs were performed to achieve more uniform feed distribution on the distribution plate of the crusher. The optimum feed chute design obtained from the designed simulations was constructed and installed in one of the cone crushers of the Sarcheshmeh copper complex and the crusher performance was monitored for a period of 15 months.

METHODS

In order to predict the feeding arrangement, a 3D DEM based (parallelized using CUDA technology) software called $KMPC_{DEM}^{©}$ was used. The development of the software started in 2013 at the Kashigar mineral processing research center (KMPC) in Mining Engineering group, Shahid Bahonar University of Kerman, Iran. Full access to the software source codes enabled us to add or modify the algorithms and related relationships. Since the previous version of software in terms of number of geometries involved in the simulation was limited to one geometry, in order to simulate the overall crushing circuit, it was necessary to develop codes by optimizing the data exchanges from 3D design software. Based on our experiences in using the object files for single-geometry simulations and easy decoding of these files, .obj format was used by applying a few changes. For instance, an assembly 3D file (SLDR file including all geometries involved in the simulation) must be created to link the geometries together with specific properties of each geometry. Then, each geometry is imported while hiding the other geometries. In this way, it was possible to mesh the geometries separately and attribute the features of geometries (e.g., speed and type of motion or the entrance position of particles) to their meshes and also record the related data (e.g., acting tangential and normal forces).

FINDINGS AND ARGUMENT

The DEM simulation of the material flow through the conveyor belt into cone crusher concave with the original feed chute design (i.e., cubic) is shown in Figure 1. The inspection of the simulation indicates a high degree of non-uniform feeding.

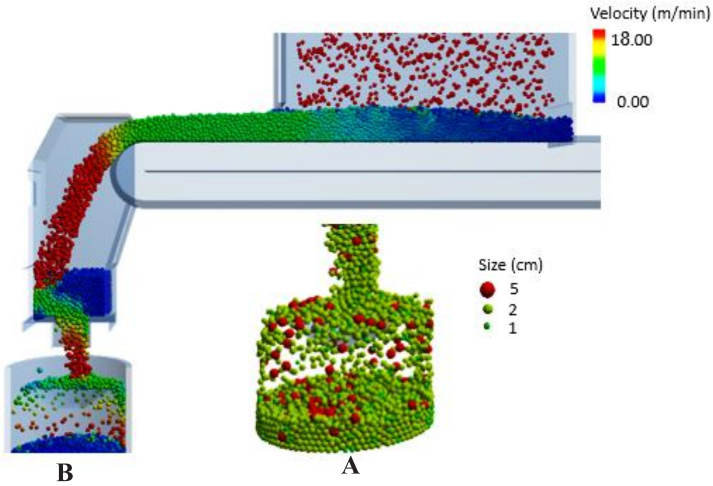

Figure 1. Simulation of material flow in tertiary cone crusher circuit: particles are colored by **A:** size; red: large, dark yellow: medium, light green: small, **B:** velocity; red:18 m/min, blue: 0

To provide a clearer picture of the phenomenon created by the segregation in the crusher concave, a horizontal cross-section of the distribution plate of the crusher along with density distribution is depicted in Figure 2. There is a severe segregation indicated by a high density of large particles in the lower part of the distribution plate (Figure 2).

Figure 2. Density distribution chart for cubic feed chute (particles are colored by size; red: large, orange: medium, green: small)

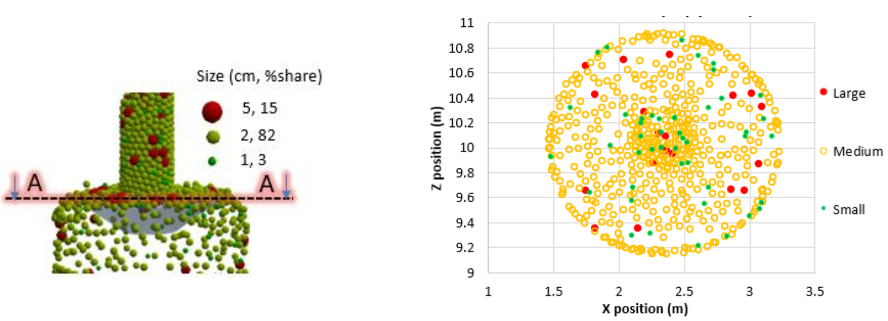

Figure 3. Density distribution chart for the cylindrical feed chute (particles are colored by size; red: large, orange: medium, green: small)

Figure 3 shows that there is a symmetrical distribution without segregation and vertical flow of feed into the chamber of crusher clearly has been obtained for new chute design.

In order to establish a sound base for the comparison, the power draw, throughput and product size distribution of crusher were monitored. A period of eight months before and 15 months after the installation of new feed chute was chosen for the comparison. The variance of power draw decreased about 26% which indicated more stable process resulting in the easier automatic control of the crusher (Figure 4). As a consequence, by shifting up from an average power of 131 kW to a new target of around 172 kW (i.e., 70% of nominal power), the crusher could be operated under choke feeding while staying within the power limits.

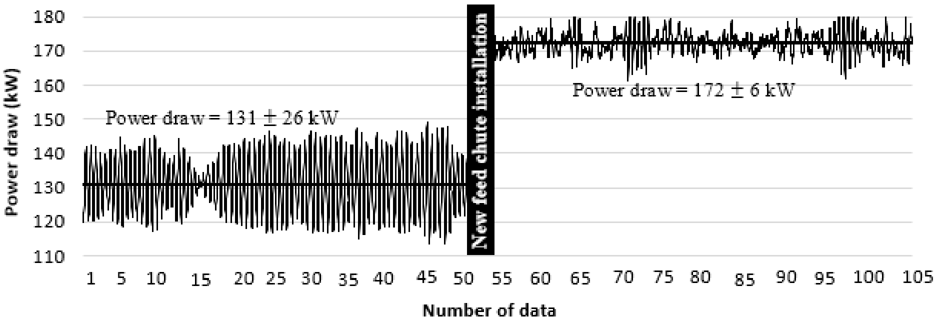

Figure 4. Comparison of power draw fluctuations before and after installation of new feed chute

The comparison of the average size of product particles along with their standard deviations before and after new chute installation showed that 100% passing size of the material retained on the screen after crusher decreased from about 48 to 24 mm. This was a result of a non-segregated feed which caused the CSS to be maintained over much longer periods of time and the product size distribution to become finer and narrower. Furthermore, wear rate on the mantle and liners of the crusher decreased which was verified by increase of the liner life from 8 months to 15 months.

CONCLUSIONS

- This work was conducted to investigate the effect of feed chute design on tertiary cone crusher performance at the Sarcheshmeh copper complex.
- A close monitoring of the performance crusher revealed that main problems were high fluctuations of power draw and uneven and high-rate wear of crusher liners. Such pitfalls were clear evidences of an improper feeding arrangement into the crusher.
- Various feed chute designs were employed in the simulations by an in-house developed DEM software called $KMPC_{DEM}$© to find more uniform feed distribution on the distribution plate of the crusher.
- The best setting of factors characterizing the cylindrical feed chute design was 0.24 m^2, 45 cm and 95 cm for surface area, and the cylinder length above and below the feed chute, respectively.
- Evaluation of tertiary crushing performance having an installed new feed chute over a period of 15 months showed a reduction of 26% of crusher power draw fluctuations, finer and narrower product size distribution and low rate and uniform wear on mantle and liners of crusher.

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