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Operational parameters affecting the vertical roller mill performance

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ABSTRACT

Vertical roller mills (VRM) have found applications mostly in cement grinding operations where they were used in raw meal and finish grinding stages and in power plants for coal grinding. The mill combines crushing, grinding, classification and if necessary drying operations in one unit and enables to decrease number of equipment in grinding circuits. Sustainable operations and proven benefits of the technology in cement grinding applications attracted interests of the mineral industry. Within the scope of the study, ore grinding performance of the VRM was investigated via a mobile grinding plant and relationships between operational parameters were identified. In this context, gold ore was ground under different process conditions. The samples collected after the test works and size distributions were determined. As a result of the study, effects of operational parameters such as working pressure, and classifier rotor speed on product mass flow and product size were investigated. In addition, correlations of specific energy consumption of the grinding-classifying circuit with product rate and product size are presented. The aim was to develop a VRM performance prediction model that is based on input data from characterization combined with the knowledge of the interaction of the single grinding parameters.

1. Introduction

Comminution is highly energy consuming and the head operation of the entire processing plant where the target size required for subsequent unit operations e.g., leaching or flotation is produced. Therefore, energy efficient grinding technologies have become the main interest of the industry. Up to now, various types of machines differing in grinding and operating mechanisms have been developed to meet the requirement of the industry. With the introduction of the high compression machines such as High Pressure Grinding Rolls (HPGR), Vertical Roller Mills (VRM) and Horomills, efficiency of the grinding circuits was improved in terms of energy and downstream effects. Among these devices, vertical roller mills have an important position in cement and mining industry.

In literature, there are many studies performed in cement plants on comparison of conventional grinding systems and vertical roller mills in terms of energy consumption. It was noticed that 30% energy saving could be provided by VRM for cement grinding (Schaefer, 2002). Similar conclusions have also been drawn by Tamashige et al., 1991; Ito et al., 1997; Roy, 2002; Simmons et al., 2005; Jorgensen, 2005. The classifier performance has a significant effect on this improvement of VRM grinding efficiency. The classifier reject material creates coarser material bed on the table. The coarser bed increases the grinding performance, because finer material in bed cause cushion effect. An efficient classifier leads to decrease in grinding energy consumption and vibrations as well (Schonbach, 1988; Becker et al., 1993).

In recent years, pilot plant tests with the Loesche Ore Grinding Plant OGP mobile were performed. The aim was to identify if the benefits proven for VRM's in the cement industry can be transferred to the mineral industry. Pilot plant test results with various ores showed that low energy consumption feature of vertical roller mills is applicable to the ore industry. Grinding test results for zinc ore showed that it is possible to decrease the total grinding energy consumption from 20.11 to 11.40 kW h/t by using vertical roller mill instead of AG/SAG-ball mill circuit (van Drunick et al., 2010). In another test performed in the Loesche test centre in Germany, 22.9% in airflow-mode and 34.4% energy savings in overflow mode were obtained for copper slag grinding (Gerold et al., 2012a, 2012b). This situation was confirmed in an OGP test campaign for chalcopyrite ore with 18% less grinding energy consumption over to conventional ball milling circuit (Altun et al., 2015).

In addition to low energy consumption, an increased mineral liberation achieved by the in bed grinding principle compared to conventional tumbling mill grinding could be identified. Positive effects on performance of downstream processes like flotation,

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leaching, etc. could be proven. In a study, flotation recovery of copper and nickel ore was increased from 74% to 84% and from 79% to 86%, respectively (Viljoen et al., 2001). Test studies showed that high Zn recoveries could be obtained at efficient energy use (van Drunick et al., 2010). In another study, performance of gold leaching has been improved by VRM system (Erkan et al., 2012). Beside all these the ability to crush, grind, classify and dry within a single unit, low wear rates, less floor space, etc. are other advantages of VRM system.

In this study, pilot scale tests were performed with a mobile vertical-roller-mill grinding plant to investigate the relationships between operational parameters. The identification and quantification of the grinding parameter relationships was carried out to implement these relationships into a computational vertical-roller-mill performance model.

The model consists of grinding and separation sections. For the modelling of the grinding operation, breakage rates of the particles are correlated with design parameters and material characteristics. Separation operation of vertical-roller-mill will be modelled by application of current models. The model shall enable the prediction of the throughput, the particle size distributions around the vertical-roller-mill circuit, the specific energy consumption and in a later stage the wear to be expected in dependency of ore treated. The model combines performance data from pilot and industrial plants with mineral characterization methods. The mineral characterization is based on mineralogical studies combined with results from mechanical rock fracture test work like piston and die tests. The model accuracy is going to be increased with further test and mineral characterization campaigns to be carried out.

Within this aim, grinding tests were carried out at different operating conditions. At the end of this study, the relations between operational parameters were evaluated to create a first basis for a computational performance evaluation VRM model.

2. Materials and methods

2.1. Description of the mobile plant

Within the scope of the study, grinding tests were carried out by using an LM 4,5 installed in the OGP mobile constructed by Loesche for ore grinding. The installation of the OGP in a gold processing plant is illustrated in Picture 1 Design and operational parameters of the plant are summarized in Table 1.

Loesche OGP mobile can be operated in two grinding modes characterized by location of the classification systems as air-swept and overflow mode. In this paper, studies performed in air-swept mode are presented. In the air-swept mode, the vertical-roller-mill and a high efficiency dynamic classifier are suited above each other as a single unit (Fig. 1). Material is fed to the grinding chamber and transported by table rotation to the grinding gap between the fixed grinding rollers and the mill table. Crushing and grinding take place by compressive grinding. Ground material is transported over the edge of the grinding table and lifted pneumatically to the dynamic classifier. After classifying, coarse material is sent back to the grinding table and combined with the fresh feed. Classifier fine product is collected as final product in a following bag filter.

Picture 1. Picture of the OGP mobile in gold processing plant.

Table 1
Technical specifications of the mobile VRM plant.

Throughput rate (t/h)	0.5–3
No of rollers	4
Table diameter (mm)	450
Installed power (kW)	420
Mill power (kW)	37
Heater power (kW)	300
Separator air flow (m^3/h)	1500–5000

2.2. Grinding tests with the mobile plant

The grinding test studies were performed in air-swept mode. During the tests, steady state conditions were verified through the control room data. Then samples were collected around the circuit. Totally 16 grinding tests were carried out for gold ore, whose Bond Work Index is 18.5 kW h/t. Table 2 presents the operating conditions of the mill at steady state conditions.

3. Material characterization studies

In this part of the study, the particle size distributions of collected samples were determined. To identify the effect of the final product particle size respectively the degree of mineral liberation in dependency of the product particle size a variety of different product particle sizes has been produced. Initially, dry sieving technique was applied from top size to 150 μm, then sub 150 μm size was measured using laser scattering technique. These two size distribution data were then combined to obtain a full size distribution of the collected samples. Particle size distributions of product samples are given in Fig. 2.

In addition to particle size distributions, mineralogical analysis with the focus on the degree of mineral liberation and determination of breakage characteristics are part of the vertical-roller-mill performance model study. Mineralogical analysis is a good way to evaluate the effect of vertical-roller-mill on downstream processes. For this specific ore the degree of mineral liberation is still to be determined. In previous works (van Drunick et al., 2010) an increase in the degree of mineral liberation by the usage of the VRM compared to conventional technologies could be proven. The breakage behaviour of material is critical for an accurate model structure. Therefore, it is planned to carry out compressed bed breakage tests to determine the breakage distribution function and the breakage characteristics of the gold ore.

4. Results and discussion

In order to evaluate the performance of a comminution process, energy utilization and the necessary degree of mineral liberation and hence the size reduction are the key features that need to be considered for a given device. As to be expected the specific