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Research of iron ore grinding in a vertical-roller-mill

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ABSTRACT

The total energy consumption for ore comminution will further increase within the next decades. One contribution to minimise the increase is to use more efficient comminution equipment. Vertical-roller-mills (VRM) are an energy-efficient alternative to conventional grinding technology. One reason is the dry in-bed grinding principle. Results of extensive test works with two types of magnetite iron ores in a Loesche VRM are presented here. Within these test works, mill parameters like grinding pressure, separator speed and dam ring height were varied, following a factorial design of the experiments. The effects of the grinding parameters on the liberation of valuable minerals are characterised using mineral liberation analysis (MLA). It is shown how the different mill parameters influence important performance values like energy consumption, production rate and mineral liberation. Via multiple regression analysis, an optimal parameter range can be modelled for both ore types. The parameter predictions have been successfully verified in practical test works.

1. Introduction

The energy consumption of ore comminution, especially of the grinding processes, is about to rise in the next years, due to well-known reasons. Deteriorating ore grades force the mining companies to mine and process more raw material to ensure that the refining industry is adequately supplied with ore concentrates. Furthermore, ore textures become more complex and the valuables are more fine-grained, compared to ores of the last decades, requiring additional grinding for sufficient mineral liberation. These trends may lead to a four times higher energy consumption for the comminution of the main metal ores in the year 2030 compared with today (Norgate and Jahanshahi, 2011).

The strategies against the rising energy consumption can be split in two groups: first to avoid comminution and second to use more efficient comminution technology. The application of vertical-roller-mills (VRM's) for ore grinding is part of the second strategy.

The grinding parts of a Loesche mill (Fig. 1) are a rotating table (1) with a horizontal grinding track and rollers (2), which are pressed onto the table by lever arms and a hydro pneumatic spring system. Between the working surfaces of track and rollers, particle bed comminution takes place. A dynamic air separator (3) is located above the grinding chamber, which classifies the ground particles. The transport of the particles from the grinding table to the air separator is done pneumatically. For this purpose air is sucked through the mill, entering the mill from below the grinding table, streaming upward through the louver ring (4), catching the particles at the edge of the grinding table and passing through the dynamic air separator. Air and fine fraction leave the mill into a bag house, whereas the coarse fraction is guided by the grid cone (5) back onto the grinding table for further comminution. In case of wet feed material it is possible to preheat the air flow with a hot gas generator. In summary, four separate processes take place in this compact machine: grinding, classifying, transport and drying.

A VRM offers several possibilities to control the grinding process. Altogether there are six online controls (marked with * in Fig. 1), which can be adjusted while the mill is running. Furthermore, roller geometry and dam ring height are important design features in a Loesche mill, which can be adapted to the grinding task.

Several characteristics of VRM's are advantageous for the challenges in ore industry, especially in comparison to conventional grinding technology.

First of all, particles are ground in a particle bed, which is known to be more energy efficient and usually causes a narrower

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Nomenclature

A_o	mass specific surface	P_{80}	80% passing size
B_{lib}	ratio of liberation	p_{Fl}	grinding pressure
H	dam ring height	Q_3	cumulative passing
k	regression coefficient	R^2	coefficient of determination
m_{Prod}	production rate	$W_{o,mech}$	mass specific energy consumption
n_S	separator speed	x	particle size

particle size distribution (Fuerstenau, 1992; Viljoen et al., 2001). Additionally, crushing events are predominantly generated by particle–particle-contacts or phase–phase-contacts. These contacts promote intergranular breakage and, if one phase is more fragile than the other, also preferential breakage (Fandrich et al., 1997). Both breakage modes have a selective effect and enhance the liberation of the valuable mineral phases. Downstream processes benefit from the mentioned product characteristics of a VRM, which may lead to further improvements in the whole beneficiation process.

Due to a dry grinding process no process water is required. A feature which will become more important in the next decades.

VRM's are well-established grinding equipment for various tasks in the coal and cement industry today. In terms of numbers of new installed units in the cement industry VRM's have overtaken ball mills for a few years, which makes VRM's the leading mill technology (Harder, 2010).

2. Experimental

2.1. Pilot scale mill LM4.5

For the grinding tests, a Loesche mill LM4.5 (table diameter 0.45 m) is used (Fig. 2a). This pilot scale mill is a special development for ore grinding, which is reflected by several features. The mill has four rollers, which are able to stress the particle bed with grinding pressures of up to 5000 kN/m^2. Various different roller geometries are available for grinding to generate different shear stress ratios. The standard geometry stresses the particle bed mainly with compressive stress but also with shear stress, which results from different circumferential speeds of conical shaped roller and table. Shear stress causes higher amounts of fines and ultrafines in the grinding product, but may also give rise to higher wear rates and energy consumption. Contrary to cement grinding, high amounts of fines are not advantageous for the majority of ore beneficiation processes. For this reason, shear-reduced rollers were developed. The rotational axes of the shear-reduced rollers

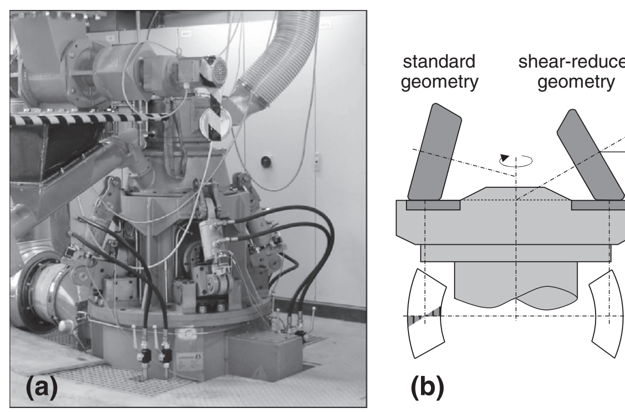

Fig. 2. (a) LM4.5 test mill, (b) standard and shear-reduced roller geometry.

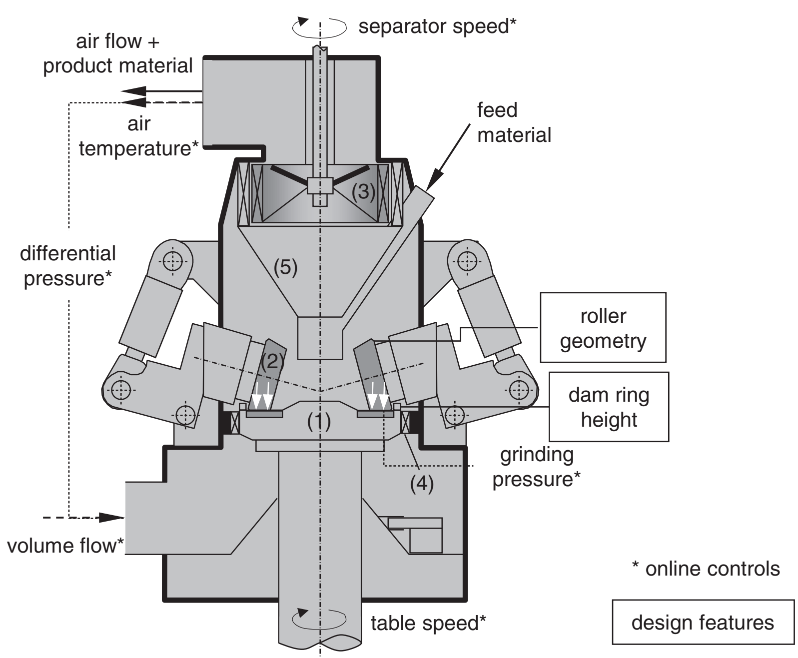

Fig. 1. Schematic operation principle of a vertical-roller-mill.