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LOESCHE VERTICAL ROLLER MILLS FOR THE COMMINUTION OF ORES AND MINERALS*

H.U. SCHAEFER

LOESCHE GmbH, Hansaallee 243, D-40549 Duesseldorf, Germany
Email: schaefer@loesche.de
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ABSTRACT

LOESCHE vertical roller mills are widely used for the comminution of raw materials in the cement industry, for the comminution of clinker and blast furnace slag and for the production of pulverized coal for cement kilns, blast furnaces and power plants. Recent research has shown, that the application of these vertical roller mills in dry grinding of ores and minerals can lead to significantly better recovery rates and higher grades when compared to conventional grinding. Since mid 2000 a LM 50.4 has been in operation for the comminution of a phosphate carrying pyroxenite ore with a capacity of 825 t/h at a D80 of 480 μm. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords
Industrial minerals; comminution; grinding; mineral processing

INTRODUCTION

The majority of grinding operations of raw materials for all kinds of industrial processes is still done by means of tube mills using wet or dry processing. Although not very energy-efficient, these tube mills are reliable, with high availability and operational safety.

Some industries, such as the cement industry, changed to dry grinding with vertical roller mills decades ago in order to reduce energy consumption and to cut down CO_2-emissions. Moreover the vertical roller mills have excellent drying capabilities. Mills with capacities up to 840 t/h @ 85 % P 90 μm are installed.

In the mid 80's, the high pressure grinding rolls were introduced first into the cement industry and were widely accepted mainly for grinding of clinker and granulated blast furnace slag, but also in particular cases for grinding of raw materials. The mineral processing industry followed and high pressure grinding rolls are accepted for certain applications and the interest in dry grinding is growing.

In the mid 90's LOESCHE introduced its vertical roller mills with the 2+2-technology for grinding of clinker and slag and for the production of cement with interground additives. Up to the end of the century, 20 mills of that kind, with a total installed power of 54.9 MW and a production capacity of more than 2,700 t/h cement and ground slag have been sold (Schaefer, 2001).

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It was a logical step to apply the vertical roller mill for the comminution of ores and minerals as well.

The South African company FOSKOR became a pioneer in dry grinding when they carried out extensive research into dry processing of the phosphate carrying pyroxenite ore (van der Linde, 1998, van der Linde and Bester, 1998) at Phalaborwa. The result of the research work was the installation of a LM 50.4 with a capacity of 825 t/h at 80 % P 480 µm.

PRINCIPLE OF THE LOESCHE MILL

LOESCHE has been manufacturing vertical roller mills for cement raw materials, clinker and slag, industrial minerals, and for coal for cement kilns, for power plants and for blast furnaces for more than 90 years. In the last three decades the cement industry demanded significantly higher mill capacities. The largest LOESCHE mill so far is the LM 63.4 with a table diameter of 6.3 m and a capacity of 840 t/h cement raw material at 85 % P 90 µm and with an installed power of up to 6 MW (Brundiek, 2000).

In the LOESCHE mill, interparticle comminution takes place in a material filled gap between the rotating flat grinding table and the conical grinding rollers. The mill feed is charged to the center of the flat table and moves affected by centrifugal forces and friction towards the table´s edge. On its way it is nipped by 2, 3, 4 or 6 conical rollers installed at the outside rim of the table. The rollers are attached to hydraulic cylinders which provide the grinding forces for comminution of the material (Figure 1).

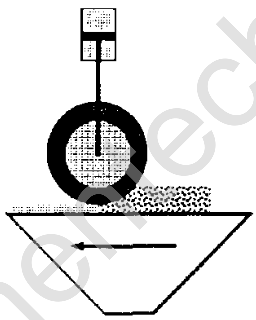

Fig. 1 Principle of comminution in LOESCHE mills.

After comminution the particles leave the table over it´s edge and are taken up by an airstream to the dynamic high efficiency classifier which is incorporated in the casing of the mill. Particles meeting product size leave the mill with the air while the reject is fed back to the table for further comminution, together with the fresh feed.

Mill design

The motor and the gear box rest on the mill foundation plate. The cast flat grinding table is supported on a segmented thrust bearing on top of the gear box in the lower part of the mill. The pedestals of the grinding rollers are also located on the foundation plate. They contain the hydraulic cylinders of the rollers. Process air also enters the mill at the lower part from two opposite locations (Figure 2).

The grinding rollers are attached to rocker arms. The rollers are equipped with wear resistant tyres made of high Cr castings. The same material is used for the liners on the grinding table.

Forced oil lubrication and the application of sealing air are used for protection of the roller bearings.

The pressure required for comminution is provided by the so-called hydro-pneumatic spring system. Figure 3 shows the principle of the hydraulic system. The hydraulic pressure on the high pressure side of the hydraulic cylinder, in the range between 50 bar and 100 bar, induces the grinding pressure into the material in the gap between the rollers and the table. The low pressure side of the hydraulic cylinder has a pressure of about 10 % of the pressure on the high pressure side. This allows a certain kind of elastic movement of the roller. By setting the pressure on both sides, the spring stiffness can be adjusted to the comminution properties of the material. Both circuits are also connected to accumulators in the near vicinity of the hydraulic cylinder which smooths the movement of the rollers even more. The result of this set up is grinding performance at a very low vibration level.

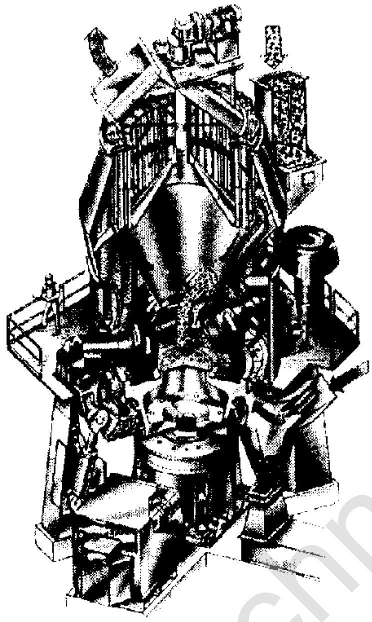

Fig. 2 Sectional view of a LOESCHE mill.

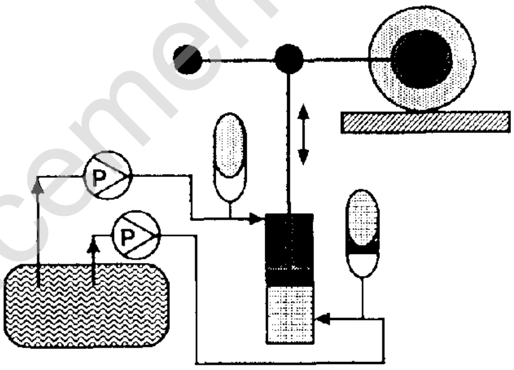

Fig. 3 Principle of the hydro-pneumatic spring system.

4 – roller mills have two individual hydraulic systems for each pair of rollers. Different pressure settings can be applied for each pair which is very helpful for material with poor nipping characteristics.

The hydro-pneumatic spring system is a very versatile feature on the LOESCHE mill because it allows easy adjustment of the grinding process responding to changing comminution properties of the mill feed e.g. due to the heterogenity of the raw material deposit itself or due to fluctuation in the moisture content etc..

The range of fineness of the feed for flotation or related processes is very well covered by the LOESCHE mill. Residues of 85 – 90 % P 90 µm and approx. 99 % P 200 µm are quite common in cement raw material grinding. Anthracite or petcoke require much higher residues of > 95 % P 90 µm and are very well processed. In cement production, or in production of ground granulated blastfurnace slag, a fineness of 90 % P 45 um and less is common.

The selection of the mill size is based on a grinding test in a small semi-industrial grinding plant in LOESCHE´s Research and Development Center, with a capacity of approx. 700 kg/h depending on the fineness of the product. During this test the abrasive properties of the raw materials are also determined.

PLANT DESIGN

Figure 4 shows the principle flowsheet of a grinding plant with a LOESCHE mill.

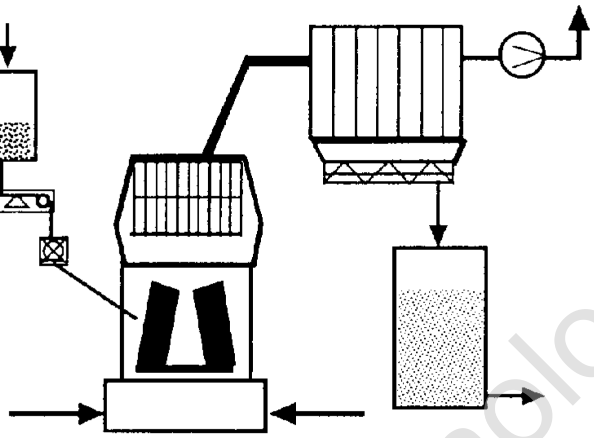

Fig. 4 Grinding circuit with a LOESCHE mill.

The raw material is fed in a controlled rate through an airlock into the mill. On the fresh feed conveyors, installations for the collection of tramp metal and foreign matter are mounted. Air enters the mill in the lower part of the housing. This air passes through the nozzle ring adjacent to the edge of the grinding table and carries the material upwards to the classifier. Draft through the mill is induced by the system fan. The finished ground material leaves the mill after passing through the rotating cage of the classifier and is collected in a filter. From there it is discharged and stored in silos for later transport to the downstream stages of processing. The storage capacity has to be critically reviewed in case reactive ores are processed. In this particular case the ground ore can be fed directly to the flotation plant and only a small buffer storage will be installed. The system fan is installed after the filter and works in a clean air enviroment. Depending on the application the filter might be replaced by cyclones (Figure 5).

In this flow sheet the air circuit is open. Grinding takes place at ambient temperatures and no drying is carried out. If the mill feed does not contain significant amounts of soft materials, such as clays or soil moisture contents of up to 2 – 3 % can be tolerated, which depends however on the product fineness as well. In the case that controlled temperatures after the mill are required, or in the case that drying of the raw material is required, the circuit can be closed and a part, or the whole volume of the air, after the fan can the recirculated to the mill as shown in Figure 5. A hot gas source might be incorporated into the circuit providing heat for drying purposes.

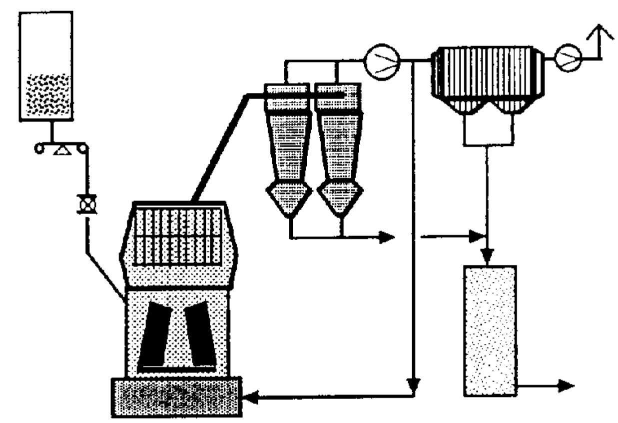

Fig. 5 Flow sheet with cyclones for product collection and recirculation of process air.

Grinding plants with LOESCHE mills can be installed outside under almost all climatic conditions. Buildings are usually not required. Compared to ball mills the noise level is significantly lower.

ADVANTAGES OF DRY GRINDING

Process advantages

The vertical roller mill offers a number of advantages compared to conventional grinding plants. In general the feed size is significantly larger (80 – 120 mm) compared to ball mills. A 3rd crushing stage might be eliminated therefore. The hydro-pneumatic spring system allows adjustment of the grinding pressure and the performance of comminution during operation. In this way the mill can cope with a large range of fluctuations of the properties of the mill feed e.g. particle size distribution, hardness, moisture etc..

The dry grinding plant can be operated independently from up- and downstream processes. This allows optimisation of the performance of the plant without interfering in other operations. The ground product is stored in silos which might act as a buffer in case the raw material processing line is shut down. Control of the density of the pulp in a floation plant is also easier.

Product advantages

In the vertical roller mill, overgrinding can be avoided to a certain extent compared to other grinding systems. The fineness and the particle size distribution of the product is controlled by means of the speed of the rotating cage of the classifier, the air flow rate, the hydraulic grinding pressure and –if installed- variation of the table speed.

In a dry grinding process the freshly liberated surfaces of the minerals are not affected by water, whose p_H or e_H might affect chemical reactions leading to a decrease in activity of these surfaces regarding later processing.

The research work of Anglo American Research Laboratory in Johannesburg, South Africa, showed that the recovery and the grade of ores can be significantly improved when dry grinding with a vertical mill (Smit *et al*,2000, Smit and Viljoen, 2000).

However due to the complex structures of the individual ores each particular case has to be studied in detail. For this reason AARL has installed a pilot plant with a LOESCHE mill LM 3.6 (capacity 300 kg/h – 2 t/h depending on fineness) on line with the down stream processing unit, such as flotation banks, in order to study the influence of the mill settings on the liberation of the minerals, as well as the influence of consumption and type of reagents and other parameters .

THE LM 50.4 FOR PYROXENITE PROCESSING

The South African company Foskor carried out an extensive study on the feasibility of various dry grinding processes for their extension of the Phalaborwa operations. In this plant an apatite carrying pyroxenite ore from the Phalaborwa igneous complex is processed. In this study the performance of a LOESCHE mill was investigated (van der Linde, 2000, van der Linde and Bester, 1998). The first grinding tests have been carried out in the Research and Development Center of LOESCHE. Later on a pilot plant with a LM 3.6 with a capacity of approx. 2 t/h and a downstream flotation unit with a capacity of approx. 500 kg/h was installed on site in Phalaborwa. The results showed that the recovery, as well as the grade of the product, ground in the LOESCHE mill was superior compared to the product from existing rod mills operating wet. Based on the results of the feasibility study, a LM 50.4 was installed in the new production line at Phalaborwa for dry grinding of 825 t/h at 80 % passing 480 μm aperture size, which is quite a coarse product for a LOESCHE mill. 3.5 MW are installed at the mill drive. The feed material size can be up to 120 mm.

Figure 6 shows the flow sheet of the grinding plant. The crushed rock is fed by means of a vibrating feeder into the mill. At the beginning of the project it was intended to take out the coarse grits rejected by the classifier and to use those grits in another process. Therefore the classifier is installed in an elevated position and a two way chute at the bottom of the grit cone allows the grits either to go back immediately to the grinding table or to be extracted from the mill and the grinding process. Due to changes during the development of the project the possibility to extract grits has not been used so far.

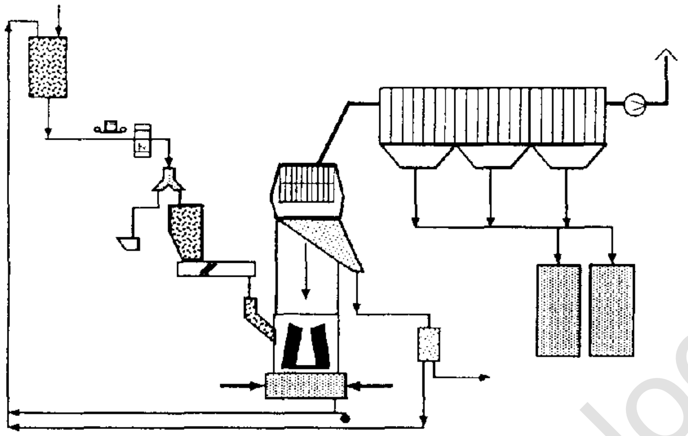

Fig. 6 Flow sheet of Phalaborwa dry grinding plant.

The product is collected in a huge double row jet pulse filter with a capacity of 950,000 m^3/h. A large settling chamber is installed in the inlet of the filter for protection of the filter bags. The filter is located in a very spectacular position on top of the storage silos . The mill is operated with ambient air only and the air circuit is open. A small hot gas generator is used fora short time when the mill is started up on cold nights in order to prevent dew point problems in the filter. The moisture content of the mill feed can sometimes exceed 2 %.

This plant has been in operation since summer 2000.

OUTLOOK

The first experiences with the application of LOESCHE mills for dry grinding of ores have proven that there is great potential for this technology, due to improved product quality and easier operation of the grinding plant, as well as the downstream process.

LOESCHE will provide substantial support for further developments jointly with mining and mineral processing companies in this sector.

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