

SELECTING THE RIGHT COMMINUTION EQUIPMENT

Dr Caroline Woywadt, Gebr. Pfeiffer, Germany, illustrates how vertical roller mills are enhancing sustainability and boosting efficiency in mineral processing.



COVER STORY

Rising power costs paired with declining ore grades and harder ores require a change in comminution equipment selection (Ballantyne and Powell, 2014). Reduced energy and water consumption are mandatory for enhanced sustainability. Dry grinding with a Vertical Roller Mill (VRM) offers benefits in energy savings: the energy consumption can be 30 – 40% lower than that of traditional tumbling mill systems in the mining industry.

The overall benefits in terms of capital and operating expenditure must be evaluated for each project alongside the sustainability benefits, taking into account not only the grinding plant but also upstream and downstream processes.

While it may not be a one-size-fits-all solution, there is a wide range of potential applications where this technology offers obvious advantages and benefits to customers in the mining industry. VRM technology delivers substantial energy savings, improves mineral liberation and recovery at coarser grind sizes, ensures uniform size reduction with a narrow particle size distribution, and achieves remarkable reduction ratios.

Comminution principle

In the VRM the particle breakage takes place in the gap between the rollers and the rotating table. Comminution is achieved by compressive and shear stress on the particle bed; the surface

contact between the particles distributes the stress in the grinding bed. With application of sufficient stress, micro cracks are generated. In the grinding bed there are multiple contact points where pressure is applied on the particles. The mineralisation in the hard parts of the ore is liberated. The opportunity for crack initiation is higher than that in a ball mill where mainly impact and shear stress is applied. The compressive comminution with an adjustable proportion (design of roller setting) of shear forces results in an energy-efficient size reduction with energy savings between 30 – 40% compared with ball mills.

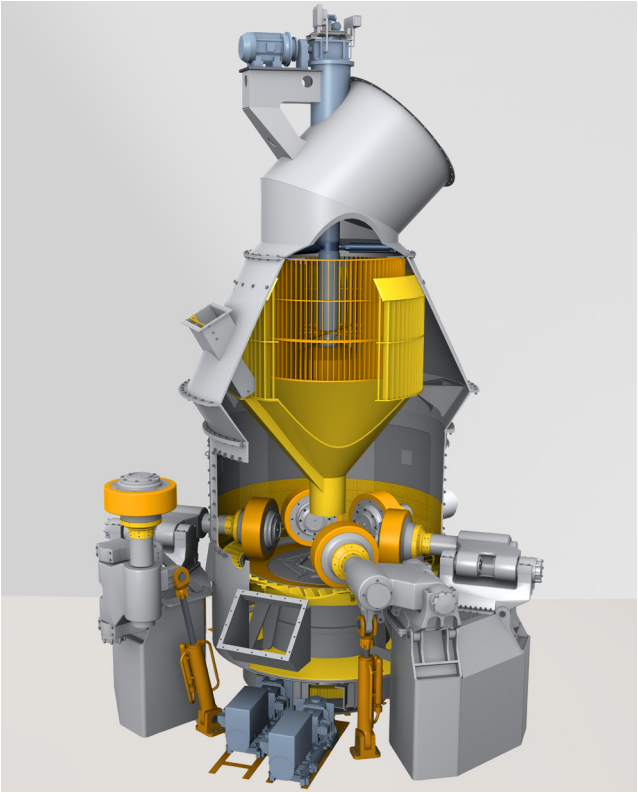


Figure 1. MVR vertical roller mill.

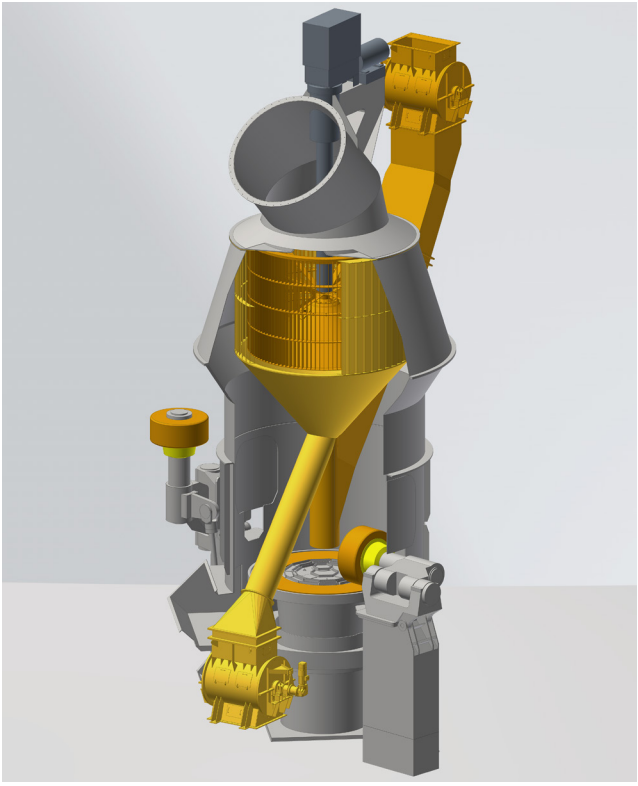


Figure 2. MVR with grit extraction.

The size reduction ratio of a VRM is much more than 1000. A feed particle size from about 175 mm can be reduced to a particle size of P80 of 1 mm – or P99 of 20 µm or less depending on the grindability and the requirements for the product.

The MVR mill is a single machine for simultaneous crushing, grinding, and classifying. If necessary, MVR even enables drying. The system can be configured according to one of several operating modes. 'Straight grinding mode' is selected for applications requiring a uniform grind size across all feed material to achieve grain liberation (Figure 1). The 'De-dusting mode' or 'Selective grinding mode' produces at least two different products. The mill is equipped with an additional grit extraction conveyor or chute installed below the classifier (Figure 2).

The classifier coarse material (grits) is collected in the grit cone and conveyed outside of the mill system. Those grits can be used as product for downstream processes or can be classified in a single separator for different downstream purposes of use. This 'De-dusting mode' applies to ores where the ultrafines contain low or nil proportions of grade material or where ultrafines are interfering with the downstream process. As an example, clay material can be removed from the ore. When used in 'Selective grinding mode', hard material from the host rock that carries no grade is removed with grit extraction and the fines leaving the classifier are the liberated high-grade ore. Physical properties of the material are used for this mode.

Feed moisture and dust separation

Moist feed materials with a moisture content of up to 4% can be efficiently ground without the need for an external heat source. This upper limit is depending on project and material properties. Within this moisture range the MVR provides high throughput rates, reduced internal circulation, and low specific power consumption, and the integrated high-efficiency classifier ensures effective material separation. The benefits of this are reduced if the feed moisture content exceeds this range.

Separation in a cyclone is more effective than separation in a bag filter for moist materials. If direct separation in a bag filter is not possible due to the high moisture content of the feed material, additional heating is required.
This cost-intensive solution can be avoided by separating the material in a cyclone. Depending on site-specific environmental conditions, a hot gas generator would therefore only be required, if at all, for short periods during annual production.

Only applications such as grinding for sinter feed or pellet feed may need the use of an external heat source for general operation, in this case direct separation in a bag filter is appropriate.

Air-swept process circuit

Vertical roller mills combine grinding, drying, and classification in a single machine. The grinding plant operates under negative pressure, i.e. a system fan is installed downstream of the cyclone or bag filter for dust collection. To obtain optimum adjustment flexibility, the system fan is equipped with a variable-speed drive

using a frequency converter. The gas flow ensures the material transport; gas volume and gas velocities produce a relatively high-pressure loss, and therefore the system – despite significant lower overall energy requirements – has a higher mill fan power consumption compared to dry grinding ball mill systems.

The pressure drop of the vertical roller mill results from the pressure drop in the hot gas duct, and the pressure drop in the nozzle ring. The difference between pressure at the classifier outlet and pressure at the mill inlet results in the total pressure drop of mill and classifier. Some equipment suppliers have the split in pressure sensors for classifier and mill, others do not. The determination of the pressure drop for the mill itself and the classifier separately gives higher potential to optimise the air swept system.

Layout

The grinding plant with the MVR mill takes up a very small footprint. Layout and maintenance concepts that are ready to be implemented are available, especially for engineering companies (Figure 3). The dimensions of the MVR 6700 M-6 plant without conveying equipment are 46 m wide by 74 m long and 57 m high. Feed conveyors will be installed as opposed to bucket elevators and material is moved on closed conveyor belts. All fans are equipped with VFD's to ensure energy-efficient operation compared to damper controlled fans.

In this case, the dust collection of the ground product is done with a cyclone system consisting of two ceramic-lined cyclones with a diameter each of 10 m. The height is about 35 m.

Due to dry operation the ground material can be stored in silos before further processing downstream. So, the grinding unit is decoupled from downstream processing systems and provides an additional degree of freedom in process application.

Wear and maintenance

In comminution circuits, it is possible that the secondary or tertiary crusher of a conventional grinding circuit can be replaced with the vertical roller mill due to the large feed size capacity. This reduces complexity, maintenance, and wear.

The changing or hard facing of rollers and table liners are typically the most time-consuming maintenance jobs that must be done regularly on VRMs. The decision between changing or hard facing mainly depends on: the landed costs of these wear parts, the achievable lifetime of the different options, and how well the annual production schedule coincides with required stops.

As a rule of thumb, the maintenance cycle is longer if the wear rate is low and, consequently, the resulting wear linings lifetime is several years. This is typical for limestone and quicklime grinding and does not apply for hard rock grinding. For an MVR 5000 R-4 raw mill, for example, with a capacity of 600 tph, a change of all roller and table liners may take about 30 hours. There is a wide variety of wear parts available – including Ni-hard, chromium alloy, and different ceramic solutions. They differ significantly in wear resistance and price.

Latest developments by Gebr. Pfeiffer are being used in industrial MVR mills. The lifetime of those grinding parts produced in-house is longer than sinter cast.

Methodology for scale-up and exemplary case studies

Grinding tests for projects are conducted in the test centre with an MVR pilot plant. The process layout of this pilot plant corresponds to that of an industrial mill. In the pilot tests not only are specific power consumption and throughput at different levels of fineness determined, but also the abrasive wear of the grinding parts and the erosive wear of the mill internals. Those figures are giving the basis for scale-up and guarantees for the mill plant.

Many iron ores, complex ores, and several pellet feeds have been tested and evaluated. The grinding of pebbles from a SAG mill copper ore processing plant was also part of a test programme and shows very promising results for grinding the pebbles in one step to the flotation fineness of a P80 of ~180µm. The grinding of pebbles in the MVR mill and not recirculating back to the SAG mill unburdens the circuit, opening for additional fresh feed in the SAG mill.

Conclusion

The MVR mill for dry grinding applications is a proven technology with many decades in industrial applications for grinding of hard to medium-hard materials. This flexible equipment reduces energy consumption to enhance sustainability and also improve the circuit's overall emissions profile in ore processing.
The comminution principle is improving liberation with higher recoveries at coarser grinding. Depending on the ore body, the grind size adjusted for flotation could further reduce grinding energy, produce coarser tailings, and decrease the footprint of the flotation circuit and solid-liquid separation.

The grinding plant with the MVR mill utilises a smaller footprint and provides additional flexibility in the circuits. Challenges such as wear of grinding parts and mill internals are recognised and are being addressed with research and development in combination with test work.

The VRM is not a one-size-fits-all solution, therefore for each project the overall benefit must be evaluated. CAPEX, OPEX, and other costs must also account for any downstream processes. The VRM is a mature technology in certain applications, but requires some adaptation in some areas for the mining industry. Based on experience in non-mining industries the challenges are known and able to be addressed. GMR

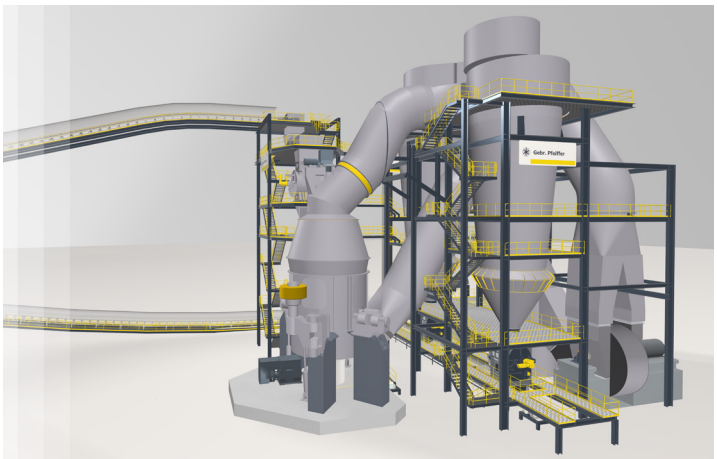


Figure 3. Mining layout.