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# Comparison of roller presses and vertical roller mills for slag grinding

The brittle nature of granulated blast furnace slag (GBFS) makes the material particularly efficient to grind in a roller press. Here authors from KHD Humboldt Wedag compare the company's systems to a vertical roller mill.

For many decades granulated blast furnace slag (GBFS) has been used as a replacement for clinker in the cement manufacturing process. Normal slag cements typically contain 40-70% GBFS, although some special products can contain more than 90%.

GBFS is a byproduct of the reduction process in the production of raw iron. The latent hydraulic properties of finely ground GBFS, as well as its low development of heat of hydration during setting, makes GBFS cement perfectly suited for massive concrete constructions such as foundations and dams. GBFS cement is also increasingly used in road construction, for example in India.

In the production of ordinary Portland cement (OPC) efforts to reduce embodied energy are focussed on the kiln because OPC contains almost 100% clinker. In contrast, the focus for reducing embodied energy in GBFS cement is the grinding step. This is because GBFS is already available as a by-product from iron production. The glassy structure of the GBFS results in highly efficient high pressure comminution.

In 1977 Prof. Schönert of Clausthal University applied for a patent with the title, *'Method of fine and very fine comminution of materials having brittle behaviour.'* Based on his findings, in 1985, KHD put the world's very first industrial roller press into operation. This roller press was designed for granulated blast furnace slag and is still in operation. Since that time KHD has continuously developed the roller press into the most cost efficient method of comminution for raw material, cement and slag.

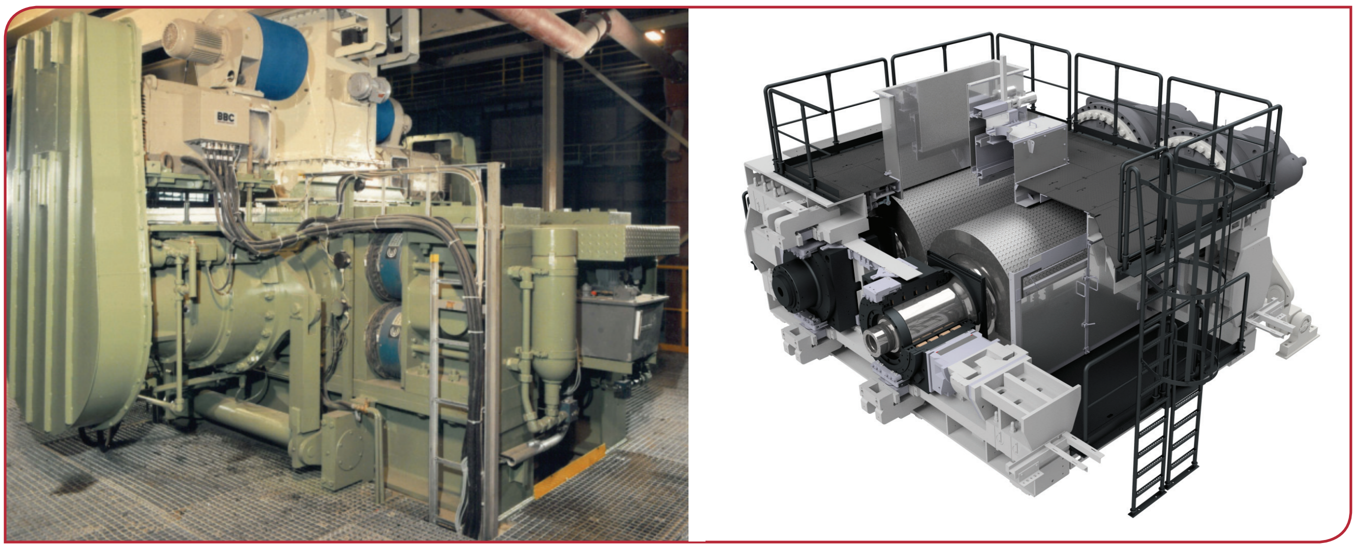
## Roller press circuits

The roller press era started with a small machine with a diameter of 1m and a width of about 60cm (See Figure 1). Small motors where mounted on the roller press frame and the rollers were connected with V belts. At that time the requested capacities were small and could be handled with small roller dimensions.

Over the years the required capacities increased drastically, which influenced the development of larger grinding systems with high outputs. KHD serves these requirements with large rollers of up to 2.8m in diameter and grinding forces beyond 30MN. That machine grinds about 160t/hr of slag meal at a fineness of 4200cm²/g according to Blaine. An overview is presented in Table 1.

All roller presses have to be embedded in a perfectly-aligned machine surround. A static separator for deagglomeration, drying and coarse separation is nowadays an absolute standard in the roller press world. This separator type, known as the V separator, was invented by KHD in the 1990s. Furthermore, a

**Below - Figure 1:** 1st Generation roller press (left) and state-of-the-art roller press (right).



| Grinding force (NM) | Roller dimensions (mm) | Raw meal (12% R90 µm) | Cement (3200cm$^2$/g) | Cement (4000cm$^2$/g) | Slag (4200cm$^2$/g) |
|---|---|---|---|---|---|
| 7 | 1700/900 | 160t/hr | 65t/hr | 35t/hr | 35t/hr |
| 10 | 1700/1100 | 200t/hr | 80t/hr | 45t/hr | 40t/hr |
| 13 | 1700/1400 | 260t/hr | 100t/hr | 60t/hr | 55t/hr |
| 16 | 1700/1800 | 340t/hr | 135t/hr | 75t/hr | 70t/hr |
| 20 | 2000/1800 | 420t/hr | 180t/hr | 100t/hr | 95t/hr |
| 24 | 2200/1800 | 500t/hr | 215t/hr | 120t/hr | 115t/hr |
| 27 | 2500/1800 | 600t/hr | 260t/hr | 145t/hr | 140t/hr |
| 32 | 2800/1800 | 700t/hr | 300t/hr | 170t/hr | 160t/hr |

**Above - Table 1:** Roller press standard sizes and capacities.

dynamic separator for the final cut point is needed, which KHD calls SKS. The necessary machinery is one point but the other is the arrangement of all components.

In 2007 KHD Humboldt Wedag pioneered an energy efficient and highly flexible comminution system that uses the roller press as the key piece of grinding equipment. Its name, COMFLEX®, is derived from COMminution and FLEXibility. COMFLEX® is the result of continuous development and represents the benchmark of modern roller press grinding technology, combining the roller press with a static separator and dynamic separator. To lower the building height, another arrangement was developed over the past three years. The GrindX® circuit operates without any bucket elevator and with a minimal civil structure. The unique design of both grinding solutions (See Figure 2) features a complete disconnection of separation and grinding to achieve the highest possible efficiency and other advantages that are described below.

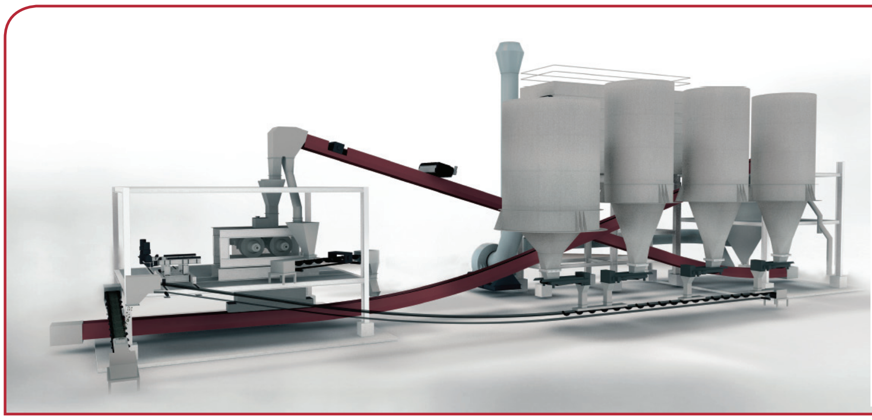
## Vertical roller mill circuits

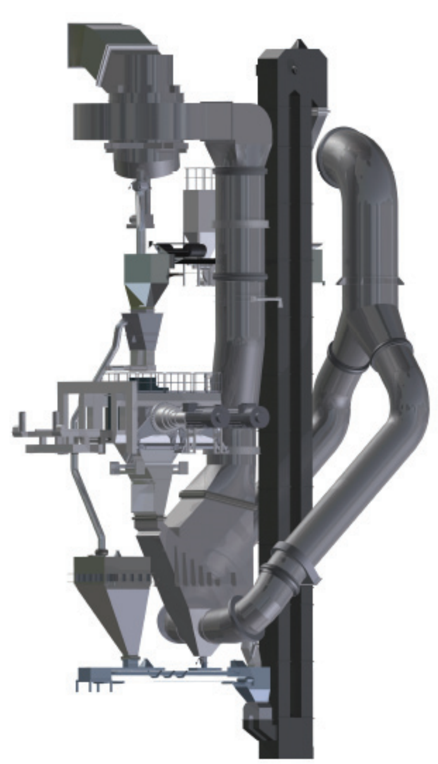
Vertical roller mills (VRM) have also been used in the cement industry for many decades. For the grinding of raw material, cement and slag, VRMs are a proven and well accepted grinding machine. In the flow sheet below (See Figure 3) a typical VRM system is shown for the grinding of different materials. The special design of the VRM combines the separator and grinding device in one housing, which allows a compact design. However, on the other hand this excludes the treatment of all material between separator and grinding device. This means that some material that falls through the nozzle ring is transported with belt conveyors and bucket elevators back to the feeding point of the VRM. Only that material can be treated with magnets to take out foreign particles.

## Handling of wear issues in both systems

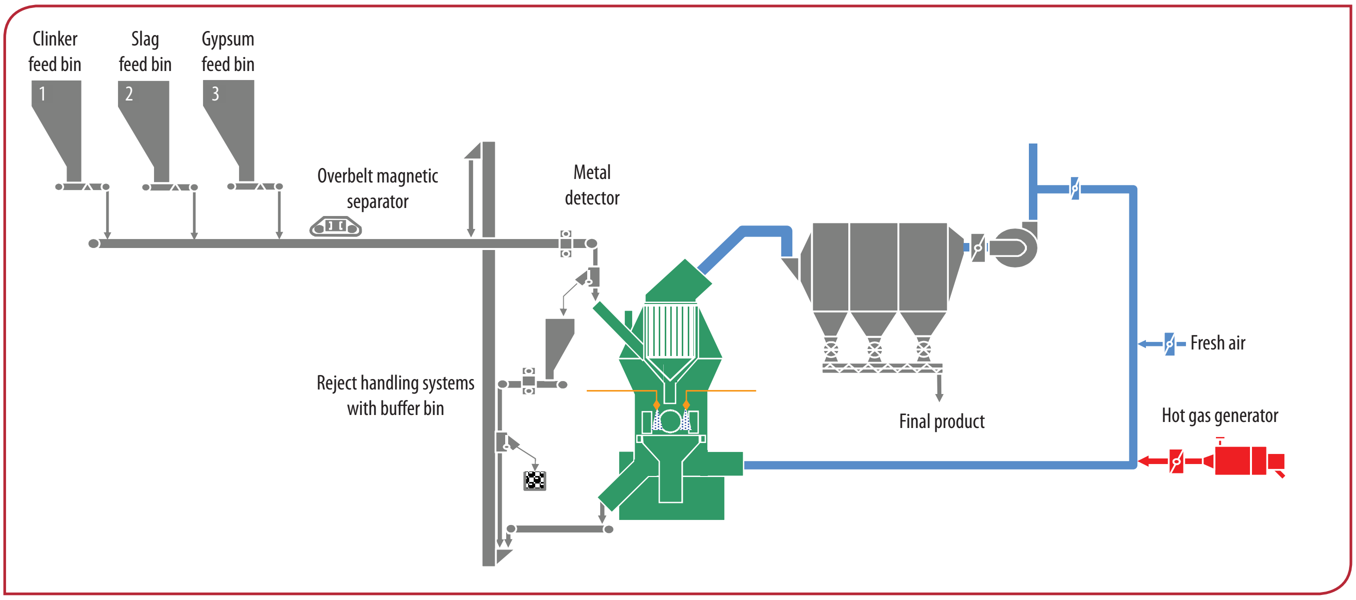
A very high proportion of the wear in the system comes from the pig iron in the fresh slag and is dissected during the treatment with the grinding tools. The general concept of both grinding machines is completely different. The VRM recirculates almost all material (only a small proportion in the external recirculation can be treated with magnets) in the housing without any possibility to extract the pig iron. Conversely, the roller press circuit allows, after every grinding zone pathing an extraction of pig iron (and composite) with magnets. This leads to more efficient and less wear-intense comminution.

A further point is the wear-resistant surface of the grinding tools. VRM and roller presses use different solutions, which lead to different results and operation times. For highly abrasive materials, a special wear-resistant roller surface

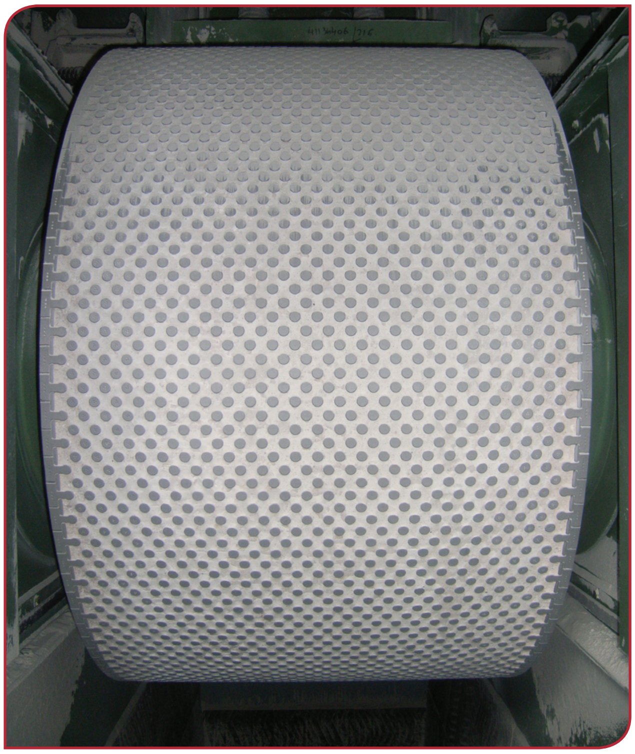




**Below - Figure 2:** 3D Model of a GrindX® (left) and a COMFLEX® arrangement (right).




**Above - Figure 3:** Example of a vertical roller mill circuit.



**Right - Figure 4:** Roller press with stud lining.

was developed for roller presses, and has proven many thousands of hours of operation. This wear resistant surface is called stud lining. It features highly wear resistant tungsten carbide studs inserted into the roller surface, which allows for the formation of a protective autogenous wear layer. GBFS is pressed between the studs, covering and protecting more than 70% of the surface. With STUD lining, an operation without maintenance of up to 25,000hr is possible and a total roller life time of more than 40,000hr, even for a highly abrasive material like slag. Wear is less than 0.5g/t.

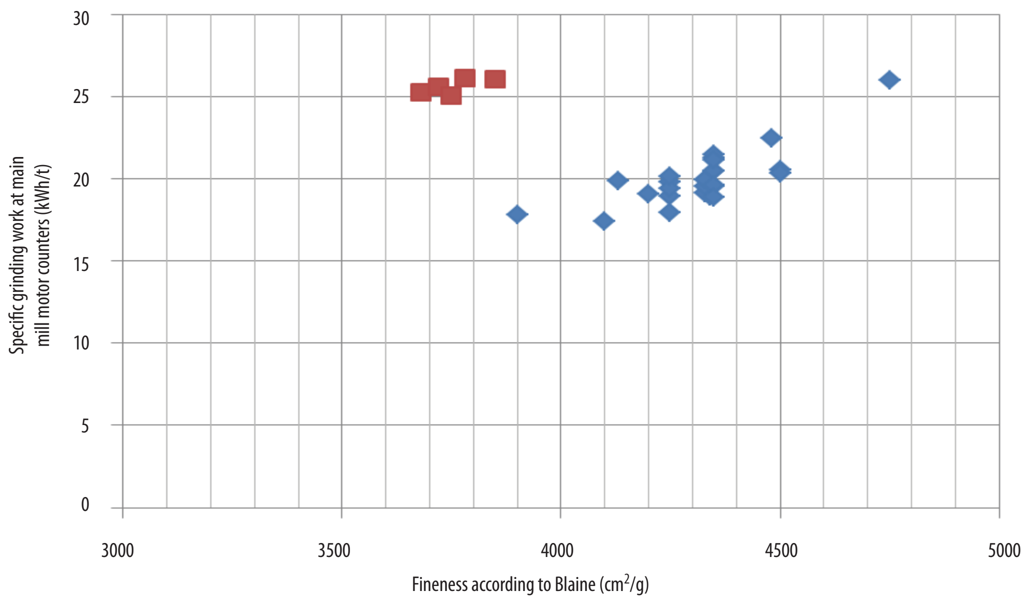
For comparison, VRM rollers are equipped with hard-faced surfaces, or more recently with composite materials and even ceramics. The reported wear rates are, however, 5-10g/t in the best cases. This means that hardfacing will have to be done 10 times or more to achieve 25,000hr of operation. As a result, several days of stoppage, costs for hardfacing and an increased risk of cracks must happen ten times more frequently than with a roller press.

## Comparison of grinding efficiency

In general it is difficult to conduct a real 'apple-to-apple' comparison of the efficiencies of different grinding methods, since slag properties, moisture, fineness, cement components or some other parameters are variable.

However, a Humboldt Wedag roller press was recently commissioned in a plant where a VRM was already installed. Both systems were installed to grind GBFS from the same yard and operators to a fineness of 3500-4500cm$^2$/g according to Blaine. In Figure 5 the consumed electrical power of the grinding tool (table for the VRM and both rollers for the roller press) is displayed for different finenesses.

It is obvious from the figure that the roller press consumes less energy than the VRM at comparable fineness. In could be detected that the roller press circuit consumes a minimum of 3-5kWh/t less energy than the VRM to grind the slag to a fineness of 4000 - 4200 cm$^2$/g. These data were collected during a very small time slot with the same feed material, which ensures very good comparability.




**Right - Figure 4:** Specific energy at mill main motor plotted against fineness.

Roller press ◆
VRM ■

## Comparison of civil quantities

For a greenfield project several months back a VRM and a KHD roller press in finish grinding mode were offered to a customer that offered comparable outputs, fineness and compositions of the cements. These offers also considered the concrete and steel portions of the buildings. Looking at Table 2 it is clearly visible that the excavation cost of the VRM is particularly high, twice that of the roller press building. This is caused by the enormous foundations that are needed to install a VRM. Roller presses on the other hand need more structure above ground. This can be seen from the slightly higher amount of reinforced steel. Overall, it can be seen that the roller press civil costs are approximately 10% lower than the civil costs for the VRM.

## Summary

KHD Humboldt Wedag has developed the roller press system over the past 30 years into the most energy-efficient and low-cost grinding system in the global cement sector.

GBFS grinding as a special field requires highly wear-resistant grinding tools and high pressure to comminute efficiently but not at the expense of excessive wear. Both advantages can be combined if granulated blast furnace slag is ground in a KHD Roller Press with stud lining. This machine, incorporated in a Comflex® or GrindX® system, represents the benchmark of modern roller press grinding technology for cement, raw material and granulated slag. As a result KHD is the undisputed market leader for slag grinding circuits.[1]

## Reference


**1.** OneStone Research, March 2016.


**Right - Table 5:** Comparison of civil costs.

| | Concrete | | Steel | | Excavation ($m^3$) | Formworks ($m^3$) | Civil price (Euro) |
|---|---|---|---|---|---|---|---|
| | Main ($m^3$) | Lean ($m^3$) | Reinforcement (t) | Structure (t) | | | |
| **VRM** | 3260 | 190 | 158 | 796 | 4000 | 4760 | 2,676,964 |
| **KHD Roller Press** | 2250 | 120 | 170 | 702 | 2000 | 3520 | 2,362,232 |