Application of the Palla™ vibrating mill in ultra fine grinding circuits

by K. Andres* and F. Haude*

Synopsis

This paper presents the vibrating mill technology and summarizes the grinding principle of ultra fine grinding. In addition, a variety of operations is described and the benefits of these different operating modes' product size and efficiency are specified. A case study of an industrial application is presented to show the integration of vibrating mills into grinding circuits. The primary focus is the overall process scheme of this technology, the installation and operating costs, as well as the design parameters required for best performance.

The vibrating mill can be used in a wide range of applications for process engineering duties.

For a wide range of applications, from soft to extremely hard products, which require ultra fine grinding, surface activation or homogenization, the vibrating mill is well proven. Due to its easy operation, versatility and operation efficiency, the PALLA™ vibrating mill gains in importance in the mineral processing industry.

Keywords: Coal, comminution, grinding, mineral processing

Vibrating mill technology

Introduction

The idea of employing a swinging motion as a grinding principle was developed in the past century. Since then the demands for product grain size in the mineral processing industry have been constantly increasing, and therefore the vibrating mill has been subject to a continuous improvement. (Figure 1.)

The general purpose of size reduction is to produce a well-defined grain size, to achieve an enlargement of the particle surface, or to decompose adhered materials. Furthermore, ultra fine grinding is applied for surface activation within mechanochemistry. When one increase the particle surface, a modification of the original mechanical and chemical character may occur as a result of mechanochemical reactions or mechanochemical activation.

Construction and operation of vibrating mills

The processing of materials of different structure and chemical composition requires a wide and versatile milling concept which can be realized with vibrating mills in the following basic sizes Palla VM, Palla 20U, Palla 35U, Palla 50U, Palla 65U as listed in Table I. The machine size reflects the diameter in cm of the grinding cylinders. The throughput depends not only on the machine size but also on various other parameters such as frequency, amplitude of vibration, arrangement of grinding cylinders and grinding media. With installed drive capacities of up to 200 kW, the Palla is one of the most powerful and versatile vibrating mills available on the market.

Figure 2 shows the typical construction of a vibrating mill. In general the vibrating mill consists of two parallel grinding cylinders (a) which are fastened to the webs (b) by way of clamps and anti-fatigue screws. This body builds a so-called swinging unit. At both ends of the grinding cylinders inlet and outlet caps (c) are flanged. Unbalanced masses (d) are placed in the centre line of the webs in cylindrical roller bearings to create the effect of circular movements of the grinding cylinders. At the height of the centre line, the shaft with bearings and with adjustable unbalances masses is connected with cardan (e) and coupled to an electric motor (f). The swinging body is supported with lugs (g) on special spring elements (h) attached to the machine frame.

Flexible airtight elements ensure a dust-tight grinding system. The grinding cylinders are protected with replaceable wear-resistant linings.

* *MBE Coal and Minerals Technology GmbH – Formerly Humboldt Wedag, Coal and Minerals Technology GmbH, Germany.*

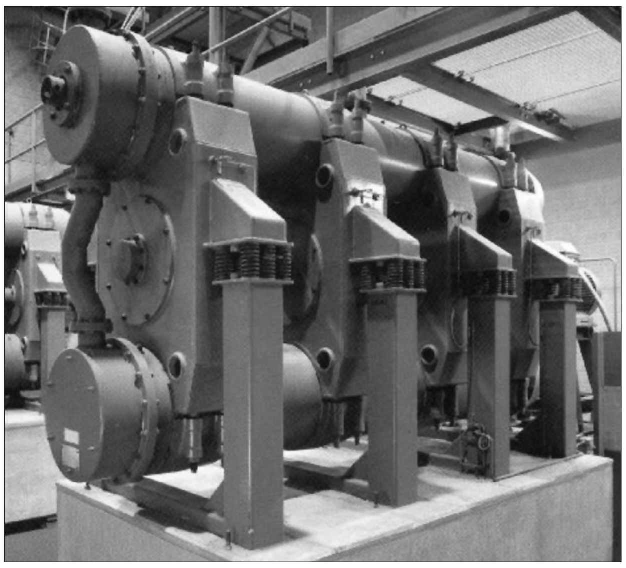

Figure 1—Vibrating mill Palla 65U

Table I

Basic dimensions of Palla™ vibrating mills

Type	Diameter (mm)	Length (mm)	Throughput (kg/h)	Power (kW)
VM	200	300/600	0.1–150	1.9
20 U	200	1,000	20–500	5.5
35 U	350	2,000	50–3.000	22
50 U	500	3,000	200–10,000	75
65 U	650	4,000	400–20,000	160

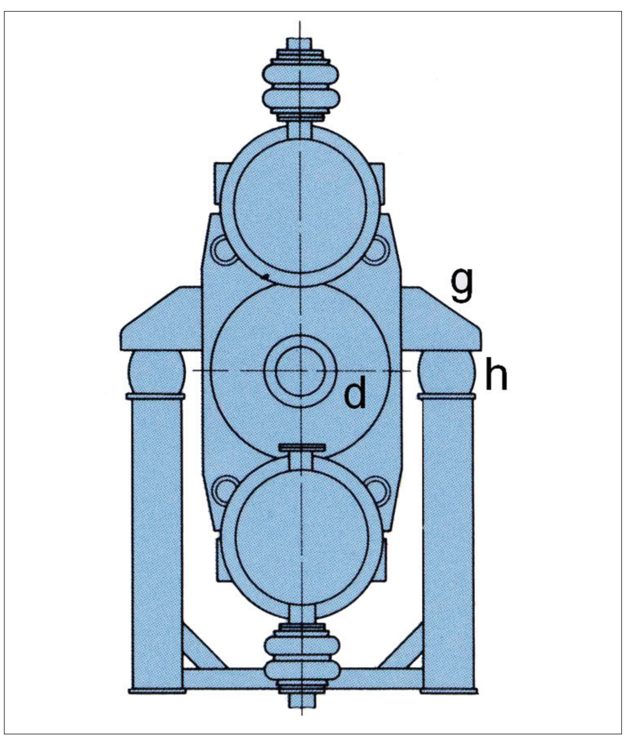

Figure 2—Sketch of a vibrating mill

The versatility of the vibrating mill can be described by the following mill characteristics and operating conditions:

- Dry or wet grinding
- Different options for grinding cylinder connection
- Continuous or discontinuous grinding
- Indirect cooling or heating
- Dust-tight, use of inert and protective gas, grinding compartment with over-pressure and negative pressure special designs
- Grinding at low temperatures (up to -180°C: Palla VM-KT or Palla 20UT)
- Different grinding media (rods, balls, cylpebs)
- Different materials for grinding media (special steel, Al_2O_3 for balls or cylpebs)
- Filling degree of grinding cylinders
- Rotating frequency
- Acceleration.

Grinding principle of vibrating mills

The vibrating mill belongs to the group of mills that make use of impact forces. However, in contrast to the so-called impact mill, the size reduction in vibrating mills is primarily caused by the impact energy of the grinding media rather than by friction or by acceleration of the feed material.

Figure 3 illustrates the vibrating mill with its grinding cylinders, filled up to 65% with grinding media.

Usually rotation impulses of 1.000 min^{-1} are transferred by the effect of unbalanced weights from the surface of the grinding cylinders to the grinding media, which performs an almost ideal circular movement. Depending on the frequency and the unbalanced mass, an acceleration of several g can be generated (g = acceleration of gravity). The grinding effect is caused by milling the feed material in between the elements of the grinding media and between the elements of the

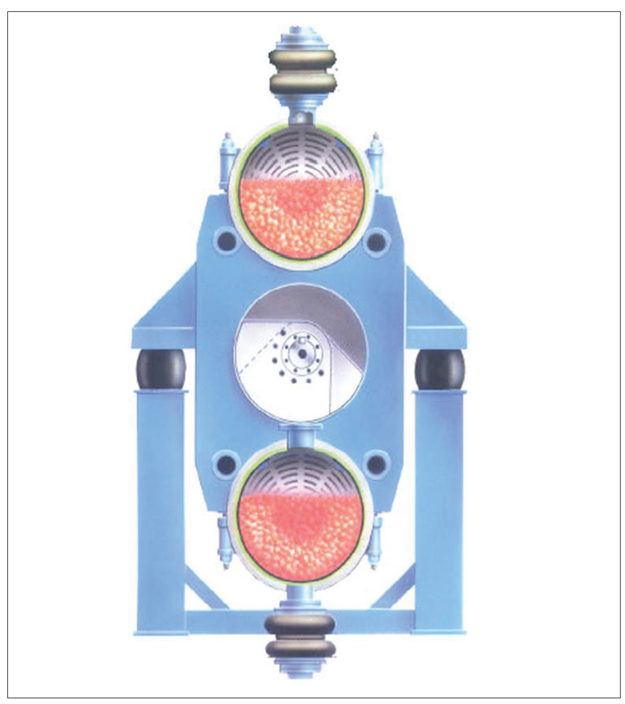

Figure 3—Vibrating mill with charged grinding cylinders

grinding media and the cylinder walls. In addition to the grinding effect based on impact energy, a minor degree of friction forces are generated between the walls and the grinding media, which also leads to a certain size reduction of the feed material. Friction results from the rotation energy of each grinding element and the relative movement of the entire grinding bed against the rotating direction of the unbalanced masses. However, the milling effect is primarily caused by impact and to a minor degree by friction only. (Figure 4.)

Furthermore a rotation of the entire grinding bed is generated due to the circular movement. Gravity is the driving force of the grinding media. Figure 5 shows the dynamics of an operating vibrating mill.

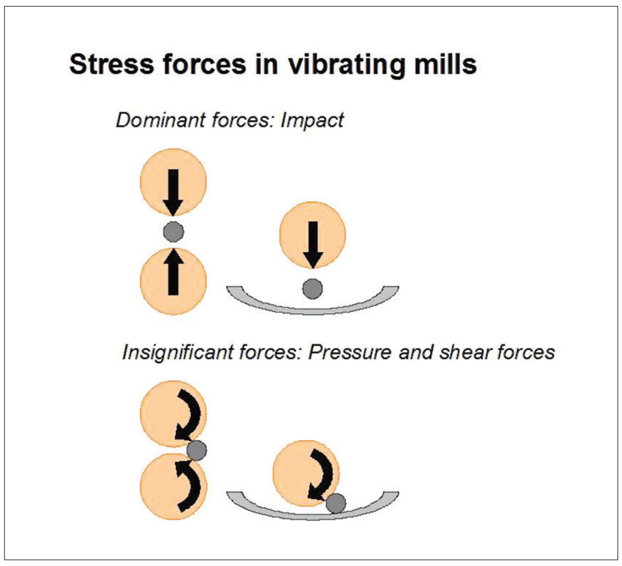

Figure 4—Grinding forces in vibrating mills

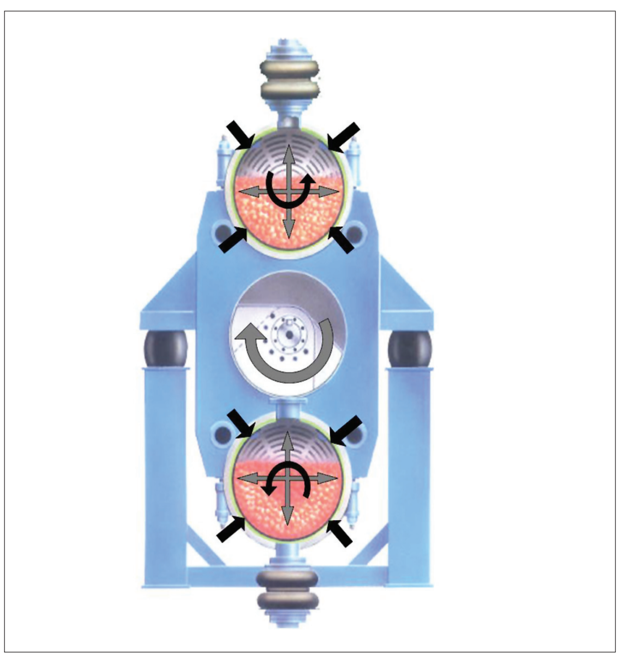

Figure 5—Grinding principle of vibrating mill

Three types of grinding media can be used in vibrating mills which, due to their geometry, cause the different impulse transitions:

Rods – linear impact energy
Balls – punctual impact energy
Cylpebs – linear and laminar impact and friction energy.

Consequently, for achieving an optimal energy transmission, the correct choice of grinding media is essential. For a coarse comminution, friction energy is rather negligible, but gains in importance within the fine zone.

Operating with rods, balls or cylpebs as grinding media shows significant differences, particularly in the coarse comminution due to the grinding media's great difference in mass. Considering these aspects and practical experiences the application range of these three types of grinding media can be set up as follows (see Figure 6).

This diagram represents the general trends in media selection. Anyway such as the specific material properties like hardness, density, grain shape, surface properties, etc. have to be taken into account.

For example, with limestone, a certain particle size generates a coating of grinding cylinder walls and grinding media, which negatively effects grindability and transportation within the mill. These coatings mainly occur when milling with balls or cylpebs, where in addition small plates can be formed, which negatively affect the grinding and any downstream air classification. By using rods as grinding media this effect can be avoided and an undisturbed operation can be sustained due to the frequency of the rods.

Not only the type but also the size of the grinding media influences the comminution result. Generally the largest grinding element should be able to retract the largest particle in the feed material. But using too big grinding media means decreasing the rating, which again decreases the comminution result. Operating the vibrating mill with too small grinding media, the feed material might pass the mill without size reduction or might accumulate and plug the vibrating mill.

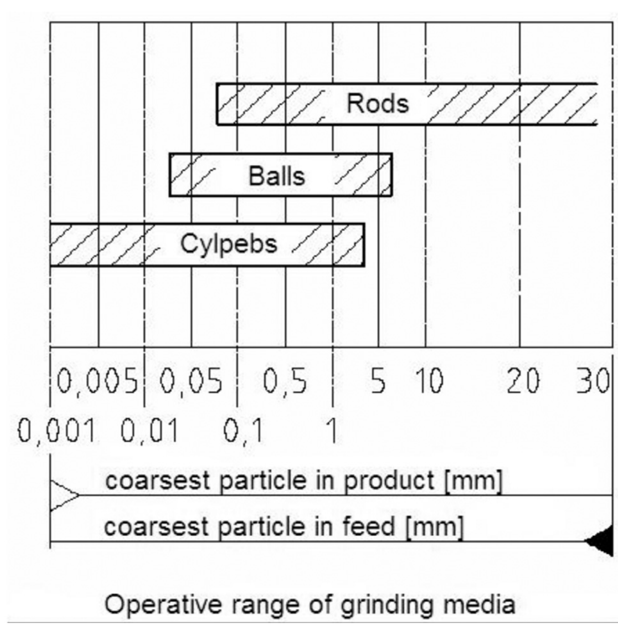

Figure 6—Application of different types of grinding media

The feed is constantly charged to the grinding cylinders and flows into the gaps of the grinding media via vibration where size reduction and transportation occurs simultaneously. Transportation of material through the horizontal grinding cylinders is based on vibration and displacement of material. The repose angle at the outlet, which controls the throughput, depends on type and size of grinding media, feed size, material properties, and circular motion.

The degree of size reduction depends mainly on retention time and on the throughput.

At the end of the grinding cylinders in-chamber screens can be installed in order to hold back the grinding media in the vibrating mill while the product material is able to pass through.

The following options for the connection of the grinding cylinders for a dry grinding process are possible:

➤ Series connection
➤ Parallel connection
➤ Center feeding.

In Figure 7 these options are shown, the selection of which mainly depends on retention time. Apart from the retention time, the grinding cylinder connection depends on the characteristics of the material so that the presented duration limits may overlap.

Series connection

With this type of arrangement, the feed passes both grinding cylinders successively, which results in maximum grinding path lengths and the longest retention times of >12 minutes.

This connection is applicable for fairly hard or coarse feed, for very fine end products, for materials which are characterized by poor blending properties, or for long grinding, dissolving, and reaction processes.

Parallel connection

With this arrangement, either cylinder yields a finished product and shorter retention times of 3–12 minutes and higher throughput rates can be achieved. Identical or different materials can be ground, blended, or chemically treated in the two cylinders at the same time.

This arrangement is suitable for materials that are easy to grind, for closed-circuit grinding, for simple blending operations and dissolving processes, as well as for chemical reactions of short duration. (Figure 9.)

Centre feeding

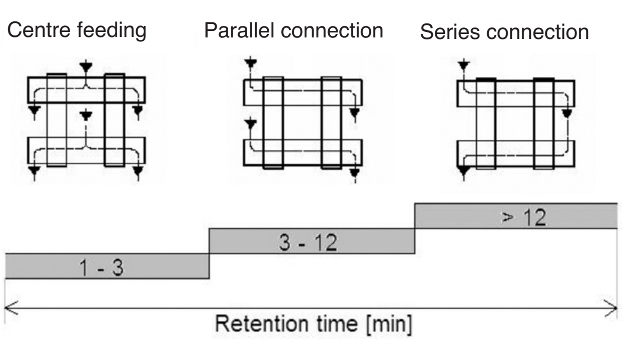

Figure 7—Options for grinding cylinder connection

In this configuration the material flows in either direction towards the outlet caps. Grinding path and retention time are very short and the throughput is correspondingly high. Size reduction is less than for series and parallel connections.

This arrangement is suitable for soft materials requiring minor grinding only or any other substance to reach a product as coarse as possible, for quick chemical reactions, or for dissolving processes. (Figure 10.)

Estimating the throughput for each material requires milling tests in which different parameters such as frequency, amplitude of vibration, arrangement of grinding cylinders, and grinding media are determined.

Since for most materials the grindability is unknown, milling tests are normally needed prior to the design of a vibrating mill. The optimal design is dependent on the application, product grain size, size distribution, grain shape, and grain surface.

The test works are executed in a small, laboratory-scale, vibrating mill. The results of this test work can be trended

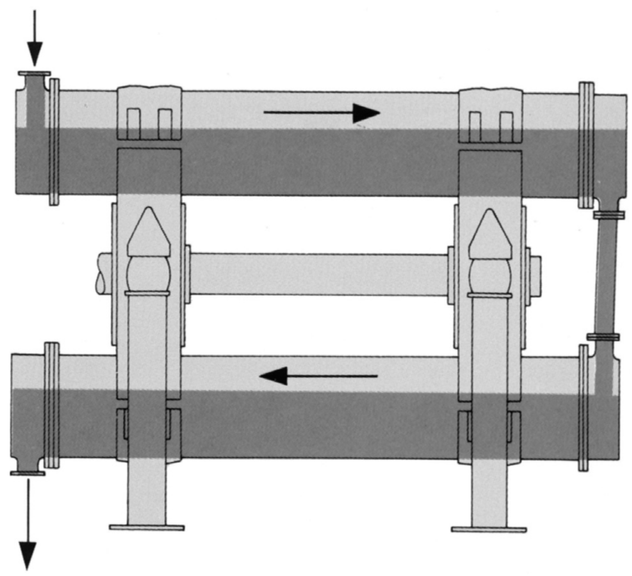

Figure 8—Series connection

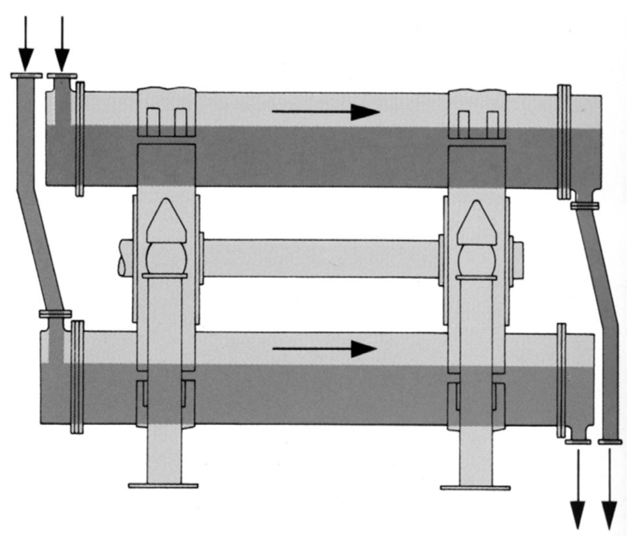

Figure 9—Parallel connection

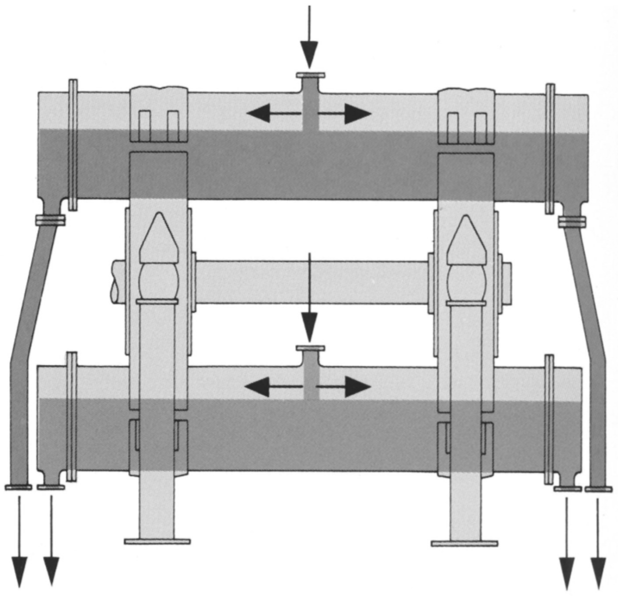

Figure 10—Centre feeding

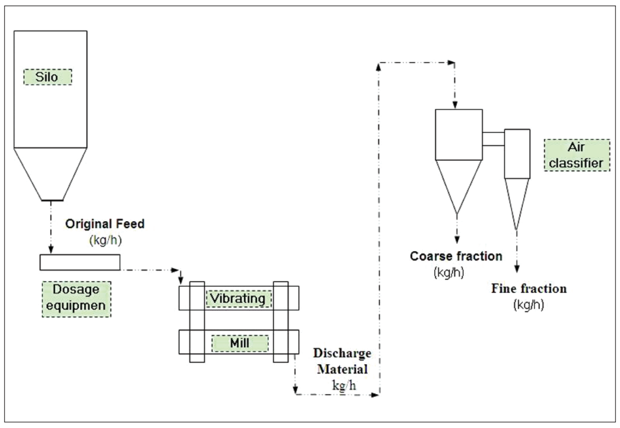

Figure 11—Air classifier—vibrating mill circuit

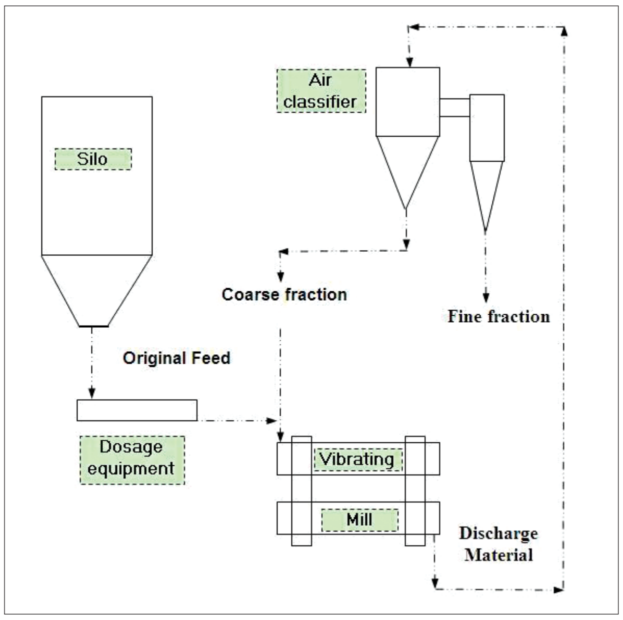

Figure 12—Vibrating mill circuit—air classifier

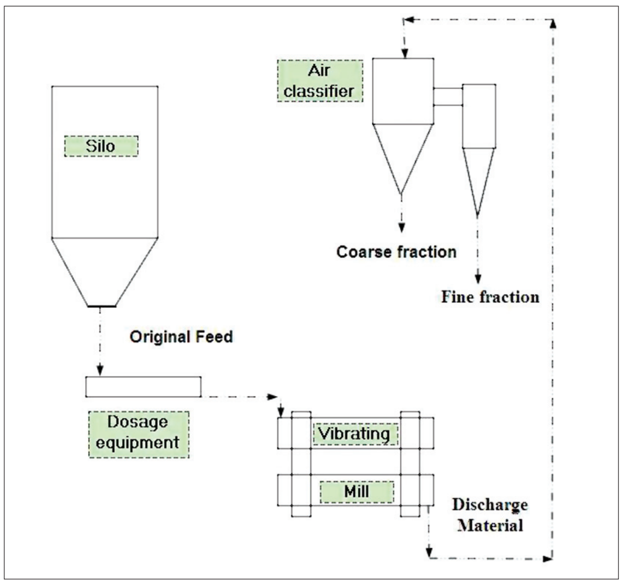

Figure13—Open circuit with an optional air classifier

and interpolated to any vibrating mill size.

Application in ultra-fine grinding circuits

For over 160 different materials, from soft to very hard, the vibrating mill has been successfully established for grinding, homogenizing, and activating. A high filling degree of the grinding cylinders and a low air throughput appear to be beneficial for materials such as metals, coal, coke, and other organic materials, which tend to increase the risk of dust explosion.

The feed size of a vibrating mill ranges from 0–15 mm (max. 0–30 mm) whereas the product size can be less than 10 μm at continuous operation. In special applications with air classifiers, product sizes smaller than 3 μm can be achieved.

Figure 11 shows an air classifier—vibrating mill circuit. The material is first fed to an air classifier before it is charged to the vibrating mill. This type of circuit is applicable if the feed material contains a lot of fines or significant fraction of the product grain size.

Figure 12 shows a vibrating mill—air classifier circuit, an option frequently applied in the mineral processing industry.

A third option operating a vibrating mill process is an open circuit with an optional downstream air classifier. (Figure 13.)

However, it appears beneficial to apply the vibrating mill in grinding circuits without an air classifier by increasing the retention time.

Case study

Application of vibrating mills for grinding of lignite

The application of vibrating mills for grinding of lignite shall be presented by an industrial example of RWE Power, the former Rheinbraun company. The coal refining plant Fortuna-Nord in Bergheim is one of three remaining plants of RWE Power.

During the process design phase in the 1970s it became evident that the fine fraction needed to be removed in order to optimize the economic efficiency. For coking two hearth-type furnaces are installed in which the dry lignite is heated on a special plate. In this process the lignite loses its residual water and its gaseous components. This process is run under oxygen deficiency in order to avoid lignite combustion. The volatile components are used for steam generation and the hot carbon is cooled down by water and air for further transportation. With both hearth-type furnaces lignite as well as activated coke can be treated.

The most profitable solution is to remove all fines < 1 mm. The fraction < 0.3 mm can be sold as filter dust whereas the coarser fraction has to be reduced in size first. In order to achieve the fineness of the filter dust RWE Power installed three Palla-type vibrating mills.

Before installing the vibrating mills, grinding tests were executed. The test results showed that the largest throughput could be reached with a frequency of 1.000 min^{-1} and when using rods as grinding media. A calculation showed that for the requested throughput of 9 t/h the Palla type 65U would be required. In 1976 three vibrating mills were installed, with centre feeding and one) minute grinding time, and the actual capacity was even higher than estimated. Subsequently nine more vibrating mills were installed. Figure 14 shows the grinding unit within the plant of Fortuna-Nord.

The feed material is transported via screw conveyor to the silos upstream of the vibrating mills. In this process it becomes obvious how simple grinding occurs by a single-pass circuit and without air classifier.

After installation of the vibrating mills the guaranteed throughput was considerably exceeded.

Due to its low volume and its low air throughput in the grinding cylinders the risk of fire is very low. The up- and downstream aggregates are connected to the vibrating mill in an airtight way, so that the vibrating mill does not cause any dust emissions.

Figure 15 illustrates that the vibrating mill discharge material contains more even fines than the filter dust.

After about 5.000 min^{-1} operating hours only a minor degree of wear of the grinding media and the wear-resistant

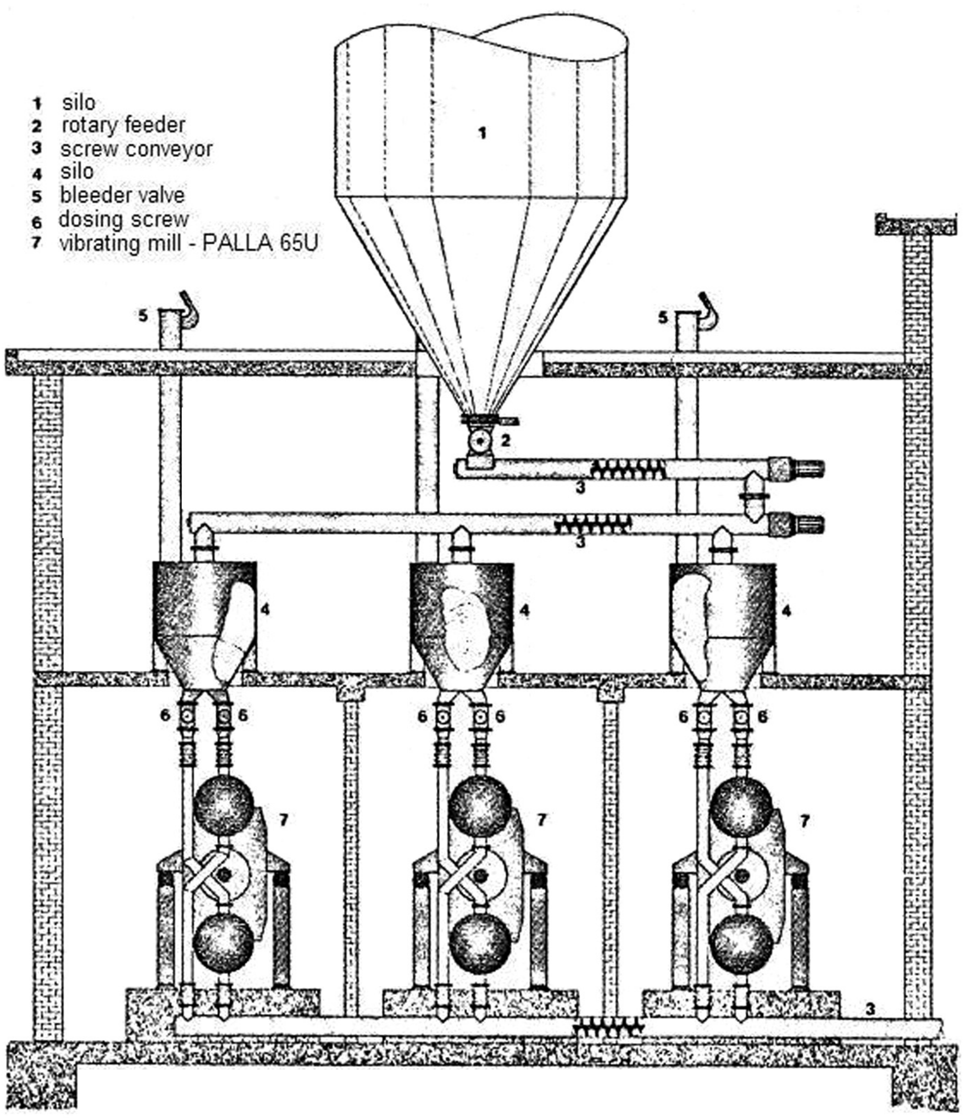

Figure 14—Grinding plant RWE Power, Fortuna Nord

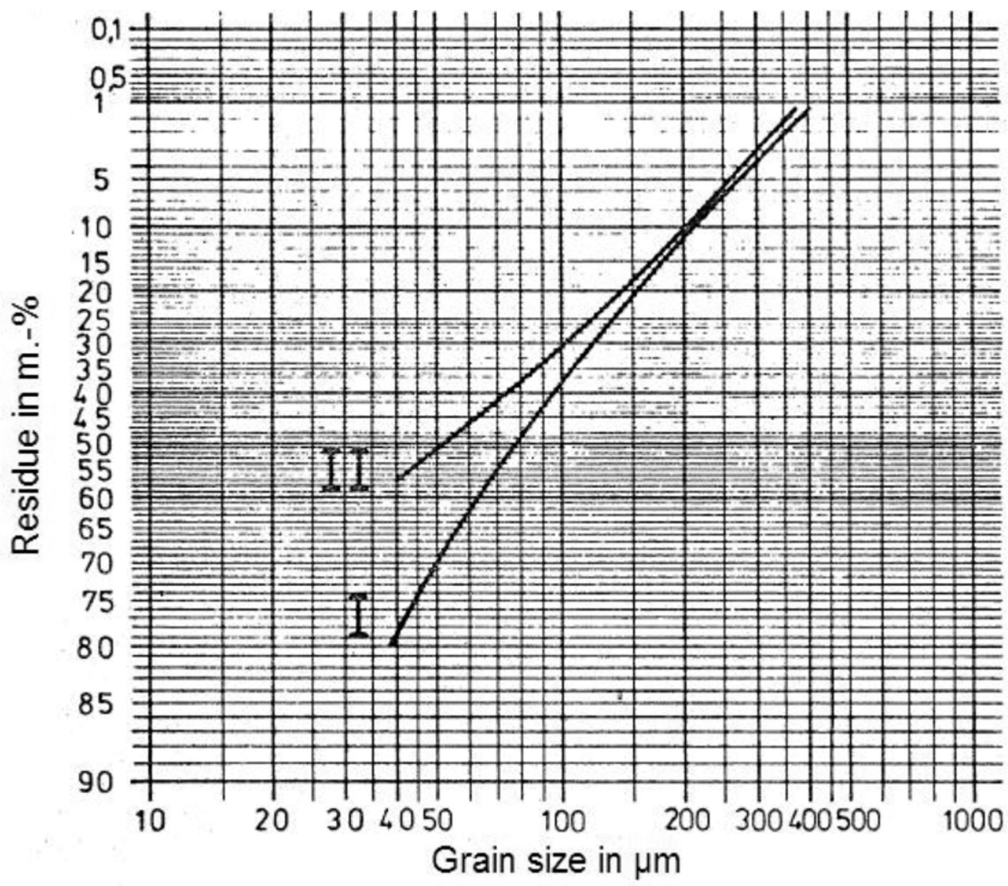

Figure 15—Grain size distribution for fine fraction of coal processing

liners can be detected. The vibrating mill requires very low maintenance.

Nowadays RWE Fortuna Nord processes 3.9 Mill. t/a raw coal, producing the three products: lignite coke, fluidized-bed coal, and lignite dust.

Two vibrating mills P50U with centre feeding are installed for the production of fine lignite coke, used as filter dust and absorber. Nine more vibrating mills P65U with centre feeding are installed to process lignite dust for industrial combustion plants. The fluidized-bed coal is lignite dust of coarser grain size, which is used for the circulated fluidized-bed technique in power plants. By this technique the whole process is made more efficient and environmentally compatible.

RWE Fortuna-Nord produces 1.57 Mt/a lignite in the following form:

- ➤ 32% lignite coke
- ➤ 21% fluidized-bed coal
- ➤ 47% lignite dust.

Conclusion

Vibrating mills have hitherto proved their worth as individual machines. Vibration grinding represents an economic and reliable solution since the required product grain sizes can be achieved in a simple continuous grinding process without air classifying and thus with a very low air flow rate, which means a very low risk of explosion.

This paper covers how vibration grinding works and the design and construction as well as the operating modes of the vibrating mill. In addition, the paper comments on the most important adaptation features. It quotes particulars of the correct type of grinding media and their size. Diagrams and figures explain and define the limits of application.

Moreover, the plants installed at RWE Power, former RheinBraun company, with vibrating mills in Fortuna-Nord are described and operational data round out the conception that a grinding plant with a group of vibrating mills can be operated economically.

This article gives a survey on the present state of vibrating mills and refers to the future development.

References

RWE Power, http://www.rwe.com, January 2008.

Hüttenhain, H. *Erfahrungen mit dem Einsatz einer Schwingmühlengruppe bei der Quarzsandvermahlung*, KHD AG; Köln, 1979.

Wehren, P. and Kortmann, F.H. Die Schwingmahlung, ein neues Mahlsystem für die Zerkleinerung von Kohle und Koks, *Journal Braunkohle*, Issue 4, 1979.

Stein, J. *Ultrafine Dry Grinding with Media Mills*, Hosokawa Alpine AG, Augsburg, 2005. ◆