14th International Research/Expert Conference
”Trends in the Development of Machinery and Associated Technology”
TMT 2010, Mediterranean Cruise, 11-18 September 2010

NEW TECHNOLOGY MAKES WET MINERAL AND ORE MILLING MORE EFFICIENT AND ECOLOGICAL

Stanislaw Serkowski
Silesian University of Technology
ul. Akademicka 2, Katowice
Poland

ABSTRACT

Ores and minerals in their natural state often contain water. As a consequence, special technology is needed to mill materials of high water content. For the most part, this situation requires milling operations to utilize ball mills while adding water in order to produce a slurry. Unfortunately, this method of removing water requires a considerable expenditure of energy.
This paper will address a new method of milling wet raw materials, which reduces both energy and water consumption. A new modification to the pendular mill uses an automatic drying system for milling materials with high water content. During the milling process, the raw material is dried inside of the machine producing a fine product with a humidity level of less than four percent.
This milling technology also makes it possible to mill such different materials as plastic clays and brittle minerals. It may also be feasible to mill deposits containing a mixture of different minerals. In comparison with conventional technology, the modified pendular mill can reduce energy consumption by 40 to 70 percent, depending on the humidity of starting material. By creating a dry fine product, the modified pendular mill eliminates the need for a spry dryer, making it possible to reduce energy consumption even further.
Keywords: wet milling, dry milling, energy saving, ecology.

1. INTRODUCTION

A number of technological processes require the size reduction of raw minerals to different degrees of dispersion. Dividing the size reduction process into crushing and milling has become customary. Crushing is a technological process aimed at bringing raw minerals to the required granularity in the grain size range of ca. decimal parts of a milimeter. Further size reduction of a granular material is called milling. Moreover, the size reduction currently required by some advanced technologies reaches the level of nanometers. As far as high tonnage ceramic or metallurgical technologies are concerned, it is commonly required that the size reduction degree is to the grain size on the order of tens of micrometers.
Milling of raw materials is the principal process of preparing metal ores for upgrading (e.g. flotation), preparing raw materials for the production of cements and ceramic bodies, and where further processing of the raw material requires a high degree of material surface development.
A common feature of all natural resources, irrespective of their mechanical properties, is their humidity. Its value oscillates between approximately two and twenty percent, depending on the raw material type, the method of its exploitation, and the climatic or geological conditions in the place of occurrence. Apart from properties such as hardness, brittleness, and plasticity, humidity is the principal factor influencing the method of milling and the design of the mill, which must have a capacity to effectively mill humid materials without prior drying.

2. MILLING OF RAW MATERIALS

The milling of useful minerals, characterised by humidity of two to twenty percent, requires the application of a wet milling process or previous drying. After wet milling, the material must be dried as well. The drying process is always necessary, since the material after milling (at least where metallurgical, cement milling, or ceramic technologies are concerned), must be subjected to granulation, briquetting, or moulding, and these require strictly defined control of humidity. In practice, the most frequently chosen method of milling humid raw materials is the wet milling process, which is convenient in terms of its technology because it does not require drying the input material in a processing plant or dedusting. The basic equipment for wet milling consists of ball mills – Fig. 1.

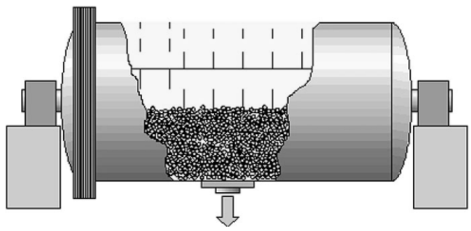


Figure 1. Ball mill

In a number of production processes, the advance in technology requires milling materials to an increasingly higher degree. The method of milling performed in ball mills restricts the possibility of modifying the ball mill design. Additionally, as the requirements regarding the milling degree increases, the ball mill becomes less efficient in terms of cost effectiveness, because its power efficiency drops as the degree of size reduction of the milled material grows.

A significant advance in the wet milling process is represented by a new generation mill manufactured by Maschinenfabrik Gustav Erich MaxxMill® - Fig. 2. [1-2]. Mechanical enforcement of the collision energy of the grinding media, and inducement of controlled circulation of the material fed into the mill, allow the achievement of higher degrees of milling at a reduced energy consumption level per unit of the milled material.

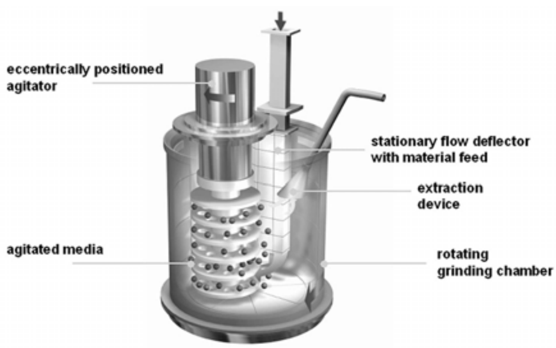


Figure 2. Scheme of the mill MaxxMill Erich, [1]

Ball mills can work in a periodic or continuous system, the latter being more effective, while the atritor-like MaxxMill always works in a continuous way and is accompanied by an oversize grain separator. In both cases, the material subject is fed into the mill in the form of suspended matter in water. Obtaining proper fluidity of such a slurry requires a water fraction of ca. 40%. Further processing of the material after milling requires removing the water, which affects the energy efficiency of the milling process.

From the point of view of efficiency of the milling itself, the principal parameter is the energy consumption per ton of the obtained material of the desirable grain size. This depends, to a large degree, on the design of the mill and properties of the material fed. In the case of ceramic bodies consisting of a mixture of "soft" minerals, such as clay or kaolin, and "hard" minerals, such as feldspar or quartz, the average energy consumption necessary to acquire one ton of material after milling, of a standard grain size degree, is from 28 to 42 kWh/t of dry material fed into the mill – Table 1.

The advance in mill design offers an opportunity to reduce energy consumption of wet milling by 15-33%. However, the fundamental opportunities to reduce energy consummation while preparing fine-grained material from mineral resources emerge when the drying stage is taken into account in the overall balance of the process.

The drying of the material obtained after milling with an average grain size of a few micrometers is carried out in spray dryers, which are plants characterised by advantageous technological qualities (high efficiency, advantageous form of granulated product dried to 5-6% humidity) and very low watt-hour efficiency.

Table 1. Energy consumed to obtain 1 ton of ceramic material with a different degree of grain size after milling [1]

Type of mill	Grains size d_{50}	Grains size max.	Energy consumption
Ball Mill - continuous	8 μm	96% < 63 μm	33 kWh/t
Ball Mill - discontinuous	8 μm	96% < 63 μm	42 kWh/t
MaxxMill (mill + separator)	6,5μm	97% < 63 μm	28 kWh/t
	3,2 μm	99% < 63 μm	32 kWh/t
	2,3 μm	96% < 45 μm	42 kWh/t

As a result from an analysis of many spray dryer installations in the ceramic industry, the typical energy consumption necessary to evaporate one ton of water is 4.7 GJ [3].

The thermal efficiency of dryers of this type reaches the level of 50-60%. Thus, from the point of view of energy consumption, they are very ineffective plants. Since spray dryers are most often fueled with gas, an additional factor is the emission of carbon dioxide, which is becoming an increasingly significant problem with costs expected to rise in the future.

The pro-ecological approach compels us to search for better solutions to the problem of milling wet mineral materials in terms of energy consumption and carbon dioxide emission.

3. NEW TECHNOLOGICAL CONCEPTION OF MILLING HUMID RAW MINERALS

There is a simple principle that underlies the development of energy-saving technology for milling humid raw mineral materials: it is better to remove humidity from the material intended for milling, rather than by first adding water and then removing it in milling installations of low watt-hour efficiency. Importance should also be attached to the fact that dry milling always takes place with a lower energy consumption. Additionally, it is important to note, that air separators of oversize grain, which considerably enhance the watt-hour efficiency of the milling, are more effective than their equivalents at separating in a water suspension.

In the study discussed, a modified roller mill was used, equipped with a hot air blowing system and an oversize grain separation system with infinitely variable adjustment of the degree of grain size reduction of the material returned to the mill.

The principal components of the installation are presented in Figures 3 and 4.

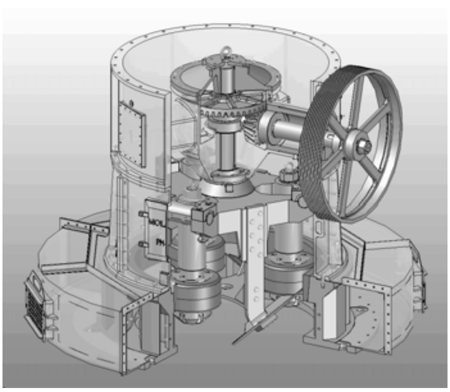


Figure 3. Pendullar mill design [4]

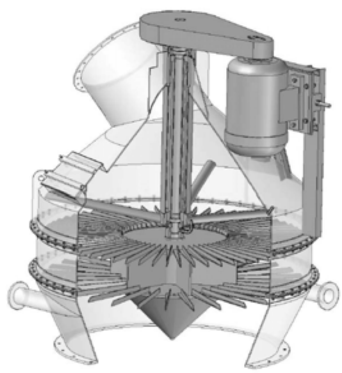
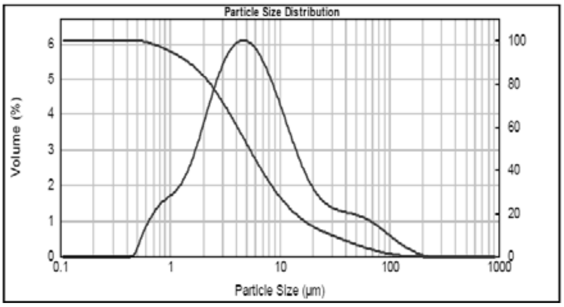


Figure 4. Oversize grain separator design [4]

Material of any humidity, restricted only by the capability of mechanical dosing into the mill chute, is conveyed to the milling roll area through a stream of combustion gas of an automatically controlled gas burner. After the temperature at the outlet from the separator stabilises at a level which will guar-

antee the required humidity of the material fed into the mill (e.g. 4%), the automatic control system adjusts the efficiency of the burner, thereby optimising gas consumption.
A number of tests were carried out using an installation equipped with a pendullar mill EMO-3, where an appropriate set of clays, feldspar and quartz, prepared according to a recipe typical for the production of ceramic tiles, served as the input material. An example of a grain curve of the material fed into the mill and the test parameters are presented in Fig. 5.



Moisture of started mixture – 9,8%
Grains size of hard minerals – 0-8 mm

Test 3:
- Set point Burner temperature; 40°C
- Mill speed: 100%
- Fan Speer: 38,5 Hz
- Classifier speed: 33 Hz
- Output moisture: 2,26%

Size (µm)	Vol Over %
63.000	3.81

Figure 5. Grain size composition of the material fed into the mill and milling test parameters in the installation with the pendular mill EMO

The consumption of energy necessary to mill a set of raw materials of humidity of ca. 10% amounted to 14-17 kWh/t, depending on the degree of grain size reduction measured by the quantity of oversize grain above 63 µm.

4. WATT-HOUR EFFICIENCY OF THE DEVELOPED TECHNOLOGY

If milling is included into the entire technological process of ceramic tile material production, including milling and formation of the granulate, the overall effects of the new technology for raw materials with humidity approx. 10% become visible – Table 2.

Table 2. Comparison of energy consumption in the new "dry technology" of preparing ceramic granulate with the traditional "wet technology".

Dry technology					Wet technology		
Milling/drying pendular mill	Granulating mixer type R	Standarization drying	Sieving	**Total**	Milling ball mill	Drying/granulation spray dryer	**Total**
80	4	50	1	**135**	50	500	**550**

The energy-saving effects, amounting in this particular case to 5-55%, obviously depend on the humidity of the input material. In the case of dry materials (humidity below 4%), which in the tested plant do not require drying at all, the energy consumption in the developed technology for preparing material for pressure forming barely reaches 13% of the energy consumed in the traditional technology, i.e. with wet milling in a ball mill and drying/granulation in a spray dryer. This effect decreases to 35% of energy consumption in the case of milling materials with an initial humidity of 15%.

5. REFERENCES

[1] Serkowski S. New Techniques of Ceramic Powders and Slurry Processing, 31 Congresso da ALAFAR Costa do Sauipe, Brazylia, 2002
[2] Hessling G., Serkowski S. „Nowe urządzenia dla technologii przygotowania gęstw ceramicznych", Polski Biuletyn Ceramiczny PAN „CERAMIKA" – 81(2003), s. 48-58
[3] Baker C. G. J. ; Mckenzie K. A. Energy consumption of industrial spray dryers, Drying technology, 2005, vol. 23, n 1-2, pp. 365-386
[4] Molaris s.l. - Company Brochure