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Application of the MaxxMill® for the Final Grinding of Unglazed Porcellanato Tile Mixes

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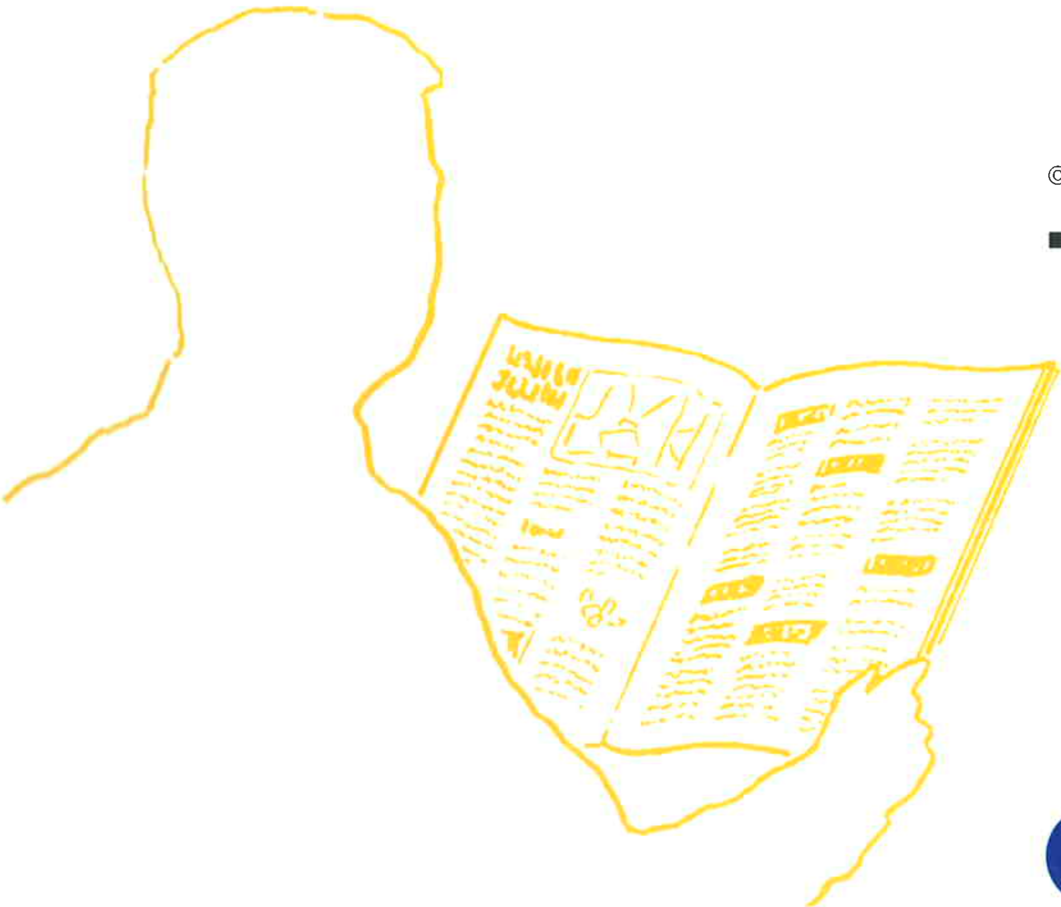

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Application of the „MaxxMill" for the Final Grinding of Unglazed Porcellanato Tile Mixes

Technological and Energy Aspects

Summary

The technological aspects in the application of „MaxxMill" (as a refining mill) in the final grinding of unglazed porcellanto tile slips produced with both continuous and discontinuous ball mills were investigated. The experiments, carried out in an Italian ceramic floor and wall tile company, were focused on the cost effectiveness of the improvements in fineness of grinding and grinding efficiency that can be achieved using the „MaxxMill". The energy savings obtained were quantified and other benefits are discussed.

State of the Art

Grinding of unglazed porcellanto tile mixes which necessitate a much higher fineness of grinding than mixes for single-fired white firing tiles has required continuous improvement of the mills to combat reduced productivity due to the low percentage of the grinding residue that is required.

Until now, three pathways have been followed to improve the efficiency of the ball mills:

Fig. 1
„MaxxMill" designed by Maschinenfabrik Gustav Eirich

- Adoption of high density grinding media, in general with a high alumina content, in place of the usual silica grinding media.
- Use of previously dry-ground hard raw materials (feldspars) in the mix composition.
- Adoption of technological expedients or mill configurations that enhance the grinding action especially during the comminution of the materials, such as, for example
  - application of devices to vary the angular velocity of discontinuous mills
  - use of continuous conical mills
  - use of classifying mill linings in continuous cylindrical mills.

When high density alumina grinding media are used, the higher mass, one and a half times more than that of silica grinding media, makes it possible to obtain a dynamic input two and a half times higher than that of the silica grinding media, and thus achieve a considerable increase in the grinding efficiency due to impact. In addition, the higher mass of the grinding media makes it possible to use smaller balls, with the further advantage of increasing the number of contacts between balls and thus between the grinding surfaces and consequently also achieve higher grinding efficiency due to attrition.

In evaluating the advantages of using high density grinding media, the costs must also be taken into consideration. Indeed, alumina balls cost ten times more than silica balls, therefore since the service life of the alumina grinding media is three times that of the silica grinding media, for the same degree of wear, the cost of the alumina grinding media is about three times that of the silica. In order to reduce grinding costs, with discontinuous mills a mixture of alumina and silica grinding media can be used, while with continuous mills having a series of large milling chambers, alumina grinding media can be used in the final chamber or mixed alumina/silica grinding media can be used in the final two chambers. Recently suppliers of continuous mills, esteeming the advantage of using alumina grinding media in terms of increased productivity, are proposing mills with a lower capacity but with alumina grinding media in all the chambers so as to limit the investment costs by exploiting the greater productivity of the mill.

The hard materials are previously dry-ground to reduce their particle size to < 125 µm (by means of an air classification system) before they enter the wet milling system. So the comminution ratio is less and therefore, for the same energy consumption the productivity of the mill is higher. Along with this advantage, however, the higher cost of air-classified feldspar which is around 50 % more than that of coarse feldspar (approx.: 1... 5 mm) must be taken into consideration. For this reason, often the choice is made to use a percentage of air-classified feldspar that ranges from 30...50 % of the total feldspar content.

With regard to adoption of techniques to enhance the grinding efficiency, the application of a frequency inverter on the motor of a discontinuous ball mill makes it possible to vary the angular velocity of the mill so as to obtain suitably diversified grinding action during the comminution of the material. In the case of continuous, conical and cylindrical ball mills with classifying linings, equipped with relief that causes lifting and a helicoidal motion, the grinding media inside the mill are subdivided according to the particle size more suitable for grinding and the yield of the mill is higher. Clearly, these more efficient systems of grinding also are associated with higher investment costs as compared with traditional grinding systems.

The positive effects of improvements obtained in the grinding process are reflected in the energy consumption. Indeed, as the grinding efficiency increases, the specific energy

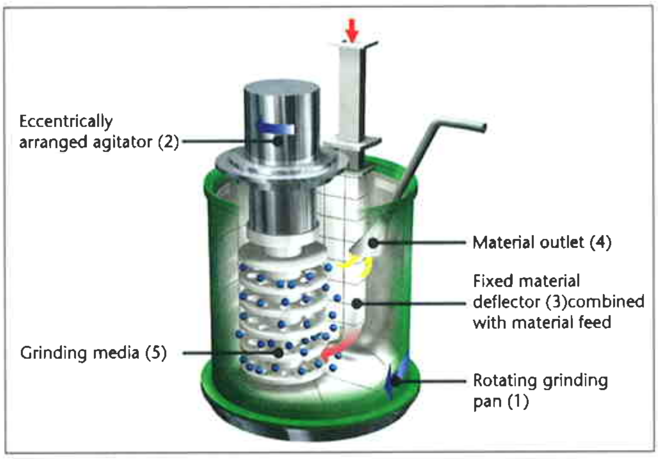

Fig. 2 Design of the „Maxxmill"

consumption decreases. This means, that for the same amount of energy consumed in the grinding operation, the productivity of the system increases.

Reported in Tab. 1 are the results of a recent survey of the energy consumption associated with the grinding process for unglazed porcellanato tile mixes. The results show that for unglazed porcellanato tile mixes (which generally are ground to a grinding residue with less than 1.5 % > 63 µm), the specific consumptions are around 50...60 kWh per ton of dry mix (moisture content = 0 %) using discontinuous mills with alumina grinding media and the consumptions decrease to 33...42 kWh per ton of dry mix when the mills are operated with variable velocity via the application of a frequency inverter.

Continuous mills which use silica grinding media have values of specific energy consumption similar to those of discontinuous mills with alumina grinding media, because the greater efficiency of the continuous system is counterbalanced by the lower dynamic input of the lower density grinding media. Continuous mills that instead use high density alumina grinding media have specific energy consumptions that are lower the greater the use of the alumina grinding media.

With regard to glazed porcellanato tile mixes (which are usually ground to a grinding residue with around 4 % > 63 µm), the specific energy consumptions are clearly lower than those for unglazed porcellanato tile mixes. In addition, for these mixes, the specific energy consumption using discontinuous mills with high density grinding media is quite similar to that of continuous mills with low density grinding media.

In the present state of the art of the grinding systems described above, the refining mill „MaxxMill", developed and produced by **Maschinenfabrik Gustav Eirich**, provides the possibility for further improvements in present grinding systems for unglazed porcellanato tile mixes.

The MaxxMill

The „MaxxMill" is an innovative wet and dry grinding system. In the following wet grinding is discussed, especially on the refining of pre-ground slip that can be prepared both in continuous and/or discontinuous ball mills.

Fig. 2 shows a schematic representation illustrating the operation of „MaxxMill" , the main components of which are (1) a rotating cylindrical grinding pan, (2) one or two eccentric agitator(s) according to the size of the machine and (3) a static deflector of the material being ground associated with the feeding tube. The agitator(s) is/are positioned eccentrically with respect to the axis of rotation of the grinding pan and can rotate in the same direction or in the opposite direction of the grinding pan, depending on the grinding effect that is desired.

MaxxMill® MM3 for the wet grinding of slip

MaxxMill® MM3 in the EIRICH Test Center

Tab.1
Results of the application of „MaxxMill" to ball mills for unglazed porcellanato tile mixes

Application to	Energy savings (increase of production)
Discontinuous mills with silica pebbles	40÷50 %
Discontinuous mills with alumina pebbles Continuous mills with silica pebbles	15÷25 %
Continuous mills with alumina pebbles in the last grinding chamber or alumina/silica mixed pebbles in the last two grinding chambers	5÷10 %
Discontinuous mills operated by an inverter (variable mill speed)	0÷5 %
Continuous mills with alumina pebbles	0 %

The grinding pan is filled to approximately 80 % of its filling capacity with small alumina grinding media beads (from 3...7 mm in diameter). The size of the grinding media depends on the particle size of the material to be ground and the fineness required. This mill operates continuously. The slip is introduced via a feeding tube at the bottom of the grinding chamber. Here the rotating movement is made in such a way that the slip is dragged to the inside of the chamber and mixed with the grinding media where it undergoes very efficient grinding action due to:

- The high pressure of the load at the bottom of the grinding chamber due to the weight of the grinding media, which develops a very intense grinding action as soon as the material enters the chamber.
- The intense movement of the grinding media which provides a high dynamic input in the area of the agitator (most of the grinding action takes place in this zone).
- Compression of the grinding media in front of the deflector produces a high level of attrition between the grinding media and material.

As a result, intense grinding actions and a high refinement of the material is achieved.

A further key element of this mill is constituted by the continuous feeding of the material to be ground in the area of the agitator. Due to the rotation of the grinding pan, which is carried out in such a way that there are no areas without grinding, and thus the grinding action is not weakened. For this reason the energy supplied to the agitator is kept high because intense contact between the grinding media and the agitator is always guaranteed and material cakings are prevented.

The grinding media consumed during grinding process will also be fed via the material feeding tube.

The ground material is continuously extracted from the upper layer of the grinding media. A separation unit separates the grinding media, keeping the grinding media inside the mill. Only the finely ground material is extracted. In this case, even high viscosity slips can be ground and extracted.

The grinding chamber and the agitator can have various types of linings, depending on the wear resistance and application required. In general ceramic or polyurethane linings and alumina grinding media are used.

The grinding action can be optimized to obtain the maximum grinding efficiency depending on the material being ground, via the choice of the volume and size of the grinding media and adjusting the speeds of the agitator and the grinding pan.

In case of wet grinding, the system is constituted (Fig. 3) by (1) a service tank for holding the slip, (2) a simple pump to feed the slip (for example a peristaltic pump), (3) „MaxxMill" and (4) another peristaltic extraction pump to unload the ground material.

The strong points of this system for grinding porcellanato tile batches are the following:

- The use of very small alumina grinding media, which makes it possible to obtain a grinding surface more than 100 times greater (compared „MaxxMill 3" with 6 mm grinding beads to 10,000 l ball mill with usual grinding ball diameters) than that obtainable with the size of the grinding media currently employed.
- The high velocity of movement of the grinding media, which (as described above) increases the grinding efficiency of the system considerably.

„MaxxMill" can be considered as an additional grinding mill, separate from the ball mills, which refines the material very efficiently. It can be used to:

- Increase the production of the ball mill, for the same fineness of grinding (grinding residue).
- Increase the fineness of grinding, for the same productivity of the ball mill.
- Grind high density slips, which leads to energy savings in the spray drying operation.

At the time being the „MaxxMill" is fabricated in two sizes, „MaxxMill 3" and „MaxxMill 5" (Tab. 2) . There is no difference in the function of these machines. Apart from the dimensions, the main difference is a second grinding agitator, which is installed in the „MaxxMill 5". Further developments are planned; the next bigger mill will be the „MaxxMill 7".

Tab. 2
Technical data on the grinding of porcellanato tile mixes in two types of MaxxMill´s

*can be changed, according to the application

Type	MM3	MM5
volume of grinding chamber	190 l	800 l
max. inst. power per agitator	37 kW	90 kW
max. inst. power grinding pan	7,5 kW	22 kW
quantity beads*	500 kg	2100 kg
number of agitator	1	2
max. installed power*	50 kW	200 kW
throughput solids*	1,5 t/h	6 t/h

Experimental

Between March and September 2002, the **Centro Ceramico of Bologna** (Italy) carried out a study of MaxxMill" at the *Cerdomus* ceramic company in Castelbolognese (Italy), producers of unglazed porcellanato tile. The objective of the study was to verify the increase in efficiency of a wet grinding system for these tile mixes when „MaxxMill" is employed downstream from the ball mill in order to obtain further refining of the slip.

The *Cerdomus* grinding division is divided into two sections, that for the preparation of unglazed porcellanato tile mixes and that for the preparation of single-fired white firing tile mixes.

The unglazed porcellanato tile mixes are ground using two continuous, 3-chamber ball mills (*Sacmi*, MTC 41) with rubber linings, silica grinding media in the first two chambers and alumina grinding media in the third chamber, and a 2-chamber, MTC 54 ball mill with an alumina lining and alumina grinding media.

Grinding the mix for single-fired white firing tiles is carried out using five, 34,000 l capacity, discontinuous *Sacmi* ball mills with alumina linings and silica grinding media.

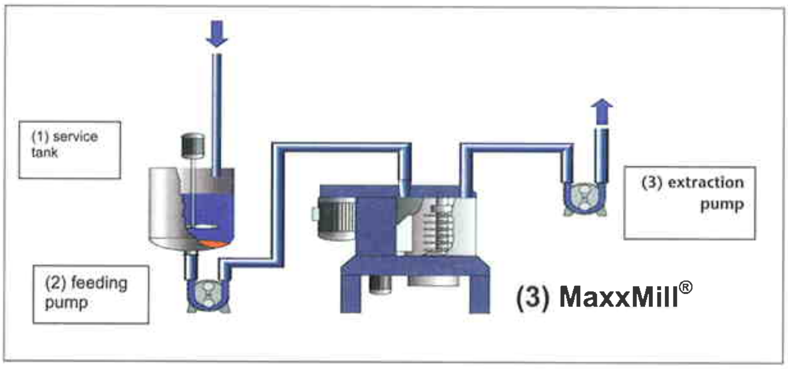

Fig. 3
Flow sheet of the MaxxMill

The refining mill used in this study was a „MaxxMill 3" with a volume of the grinding chamber of 190 l and a productivity of 1.5 t/h of dry mix (moisture content approx. 0 %). This capacity is insufficient to handle even the amount produced by the smallest of the continuous mills, therefore the experimentation was carried out with a porcelain stoneware tile mix wet-ground using one of the discontinuous mills to prepare the slip that was fed into the refining mill being tested („MaxxMill 3"). The slip coming from the ball mill was first loaded into a tank equipped with an agitator and then fed into the „MaxxMill 3". The slip exiting from the refining mill was screened, treated to remove any iron present and then stored in the tank serving the spray drier.

This experiments made it possible to:

- evaluate the influence of the operating parameters of the refining mill (velocity of the agitator and the cylindrical chamber) on performance, thus to optimize the parameters
- determine the influence of the size of the alumina grinding media, thus optimize this variable
- determine the refining capacity of the „MaxxMill 3" in function of the particle size (grinding residue) of the slip entering the refining mill, for the same final grinding residue (in the present study 0.5 % greater than 63 µm). The refining tests were begun using a slip from the discontinuous mill (density 1,700 g/l) with a grinding residue of 12 % > 63µm. The grinding residue of the slip entering the „MaxxMill 3" was then gradually reduced step by step until 4 %, the value at which it was found that the slip exiting from the „MaxxMill 3" had reached the reference value (0.5 % > 63 µm).

The energy consumptions and the production of the „MaxxMill 3" were measured in each of the tests.

Results

As pointed out already the improvement of a grinding system leads to a decrease in the specific energy consumption of the system; in other words, for the same energy consumption, productivity increases. In this study, the performance of the „MaxxMill 3" therefore has been expressed in terms of the specific energy consumption. The specific energy consumption of the „MaxxMill 3" for the refining of the unglazed porcellanato tile slip is reported in Fig. 4 as a function of the grinding residue of the slip entering the mill, for a constant final grinding residue (0.5 % > 63 µm). The graph in Fig. 4 represents the energy consumed by the „MaxxMill 3" to refine the slip. Clearly, the energy consumption is greater (and the productivity lower), the greater the grinding residue of the slip entering the refining mill. The energy consumption of the „ MaxxMill 3" necessary to bring the slip to the final reference grinding residue (0.5 % > 63 µm) was 27 kWh per ton of dry mix when the grinding residue of the slip entering the refining mill was 11 % > 63 µm, whereas the energy consumption was only 15 kWh per ton of dry mix when the grinding residue of the slip entering the refining mill was 4 % > 63 µm.

When using „MaxxMill" in combination with a ball mill, it is necessary to determine what is the most economical fineness of grinding to be achieved in the ball mill before feeding the slip into the refining mill to reach the desired final grinding residue. To do this, a study of the energy consumption was carried out on the actual systems of grinding porcelain stoneware tile mixes. In particular the specific energy consumption for the various types of ball mills in use was determined as a function of the grinding residue.

The specific energy consumptions (in kWh per t of dry mix) of the ball mills are reported in Fig.3 as a function of the grinding residue. The blue curve shows the average specific consumption for the discontinuous ball mills with alumina grinding media and the continuous ball mills with silica grinding media. The red curve shows the average specific consumption for the discontinuous ball mills operated with a frequency inverter and the continuous ball mills with alumina grinding media in the last chamber.

Based on the intersections of the curves in Figs. 4/5 , the conditions can be determined at which it is worthwhile to use the „MaxxMill 3" and what energy savings are possible.

In particular, it can be seen (Fig. 6) that in the case of the mills represented by the blue curve, it is worthwhile to grind the slip in the ball mill to a grinding residue of 8 % > 63 µm with an energy consumption of 22 kWh/t, and then refine the slip with the „MaxxMill 3" and an energy consumption of a further 22 kWh/t.

In this way the „ball mill-MaxxMill 3"-system has a total energy consumption of 44 kWh/t as compared with 58 kWh/t, the energy consumption when the ball mill alone is used to achieve the final grinding residue of 0.5 % > 63 µm. This is an energy savings of 24 %.

In the case of the mills represented by the red curve, the best choice is to reach a fineness of grinding in the ball mill of a grinding residue with 7 % > 63 µm and an energy consumption of 20 kWh/t before feeding the slip into the „MaxxMill 3" to achieve the final desired grinding residue with an energy consumption of a further 20 kWh/t. In this way the „ball mill Maxx - Mill 3" system has a total energy consumption of 40 kWh/t as compared with 42 kWh/t, the energy consumption when the ball mill alone is used to achieve the final grinding residue of 0.5 % > 63 µm. This is an energy saving of around 5 %.

Extrapolating the results to all the existing systems of grinding unglazed porcellanato tile mixes, it can be said (Tab. 1) that the advantage of „MaxxMill" is considerable when applied to ball mills with the more simple configurations and operating conditions and using the more economical grinding media

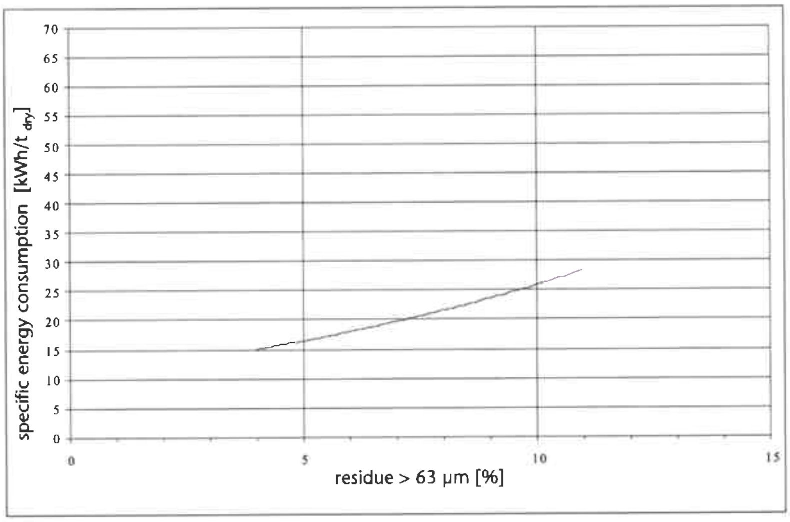

Fig. 4
Behaviour of „MaxxMill" specific energy consumption for the production of unglazed porcellanato tile mixes as a function of the grinding residue of the slip entering the mill, at a constant final grinding residue (0.5 % > 63 mm)

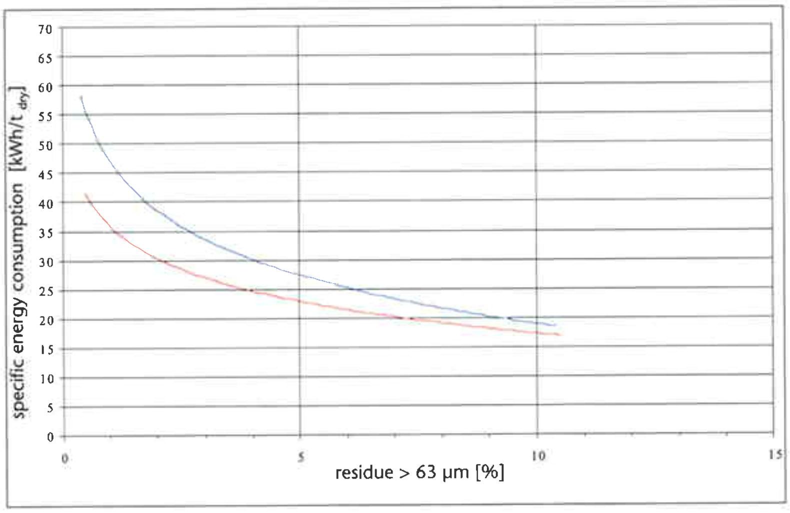

Fig. 5
Behaviour of specific energy consumption ($kWh/t/_{dry}$) of drum ball mills for the production of unglazed porcellanato tile mixes as a function of the grinding residue of the slip produced

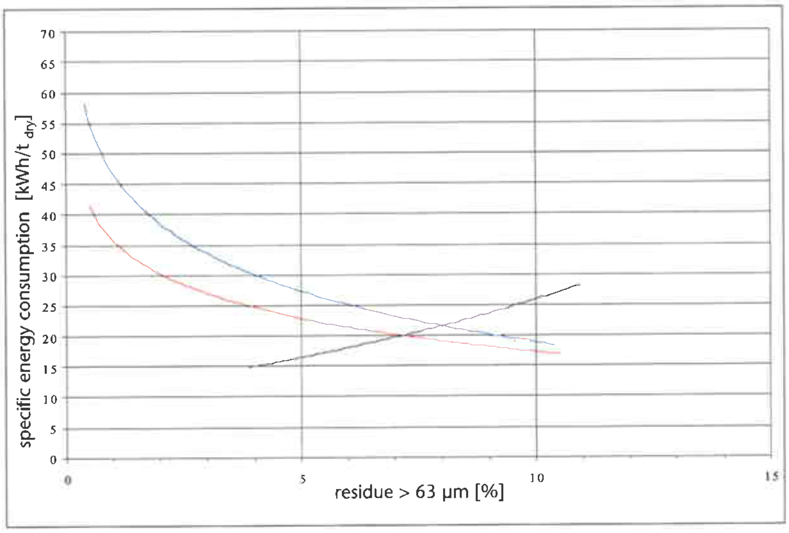

Fig.6
Behaviour of specific energy consumption ($kWh/t/_{dry}$) for the production of unglazed porcellanato tile mixes in:
- drum ball mills as a function of the grinding residue of the slip produced;
- „MaxxMill" as a function of the grinding residue of the slip entering the mill, at a constant final grinding residue (0,5 % > 63 mm).

(e.g., low density grinding media and no use of a frequency inverter), while the advantages of the use of „MaxxMill" become less and less, finally to be negligible for the more expensive ball mill systems.

We also looked briefly at the feasibility of using „MaxxMill" in the preparation of mixes for glazed porcellanato tile where the slips have a higher grinding residue. In this study, the refining „MaxxMill 3" was fed with a slip from a discontinuous ball mill (density 1,700 g/l) starting with a grinding residue of 27 % > 63 µm and gradually reducing the grinding residue of the slip entering the „MaxxMill 3" to a value of 13 % > 63 µm. With the slip entering the refining mill at this latter value of grinding residue, the final grinding residue of the refined slip was 3.5 % > 63 µm. Reported in Fig. 7 are the specific consumptions of:

- „MaxxMill" 3 in function of the grinding residue of the slip entering the mill, at the same final grinding residue (3.5 % > 63 µm) and
- the ball mill, in function of the same final fineness of grinding as that achieved with the „MaxxMill 3". The data show that grinding the slip in the ball mill to a grinding residue of 13 % > 63 µm and then refining the slip in the „MaxxMill 3" to a final grinding residue of 3.5 % > 63 µm results in a total energy consumption of 24 kWh/t as compared with 33 kWh/t when the ball mill alone is used to achieve the final grinding residue of 3.5 % > 63 µm. This is an energy saving of 27 %.

Conclusions

Considering the limitations due to the use of a mill on a reduced scale, the results of the study nevertheless make it possible to affirm the following advantages of the application of „MaxxMill" in grinding systems for unglazed porcellanato tile mixes:

- Possibility of using the more economical ball mill settings and configurations (low density grinding media).
- Possibility of using less expensive raw materials (coarse feldspars).
- Flexibility of management in the grinding division.

These advantages can all be obtained without penalizing the productivity of the grinding system and at the same time reducing production costs.

Consider, for example, a grinding division equipped with a continuous ball mill that must produce both unglazed porcellanato tiles and glazed porcellanato tiles. Generally, the mill is fed with coarse feldspar when mixes for glazed porcellanato tiles are being ground, while air classified feldspars are used in the production of slips for unglazed porcellanato tile. The use of the finer grained feldspar is necessary in order to avoid very different mill settings and the consequent longer time necessary to bring the mill to regime and resulting necessity to discard the initial pieces produced. In spite of these choices in operating parameters, the fluctuation of the technological characteristics of the slip dur-

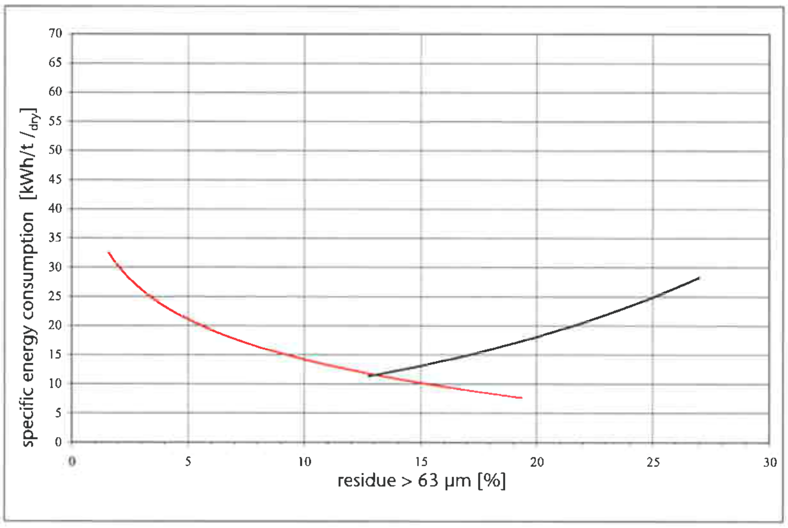

Fig. 7
Behaviour of specific energy consumption (kWh/t/$_{dry}$) for the production of glazed porcellanato tile mixes of:
- drum ball mills as a function of the grinding residue of the slip coming out;
- „MaxxMill" as a function of the grinding residue of the slip entering the mill, at a constant final grinding residue (3.5 % > 63 mm)

ing the transition is such that there are problems with the quality of the semi-worked material as well as with the final product.

The use of „MaxxMill" in the case described above would make it possible to hold the operating parameters of the continuous ball mill fixed at those for the preparation of the slip for the glazed porcellanato tiles (the slip with the higher grinding residue) and to use only coarse feldspar. When producing slips for unglazed porcellanato tile, the slip exiting from the continuous ball mill could then be fed to the refining „MaxxMill", to achieve the additional fineness of grinding required. In this way, changes in the technological parameters for the production of the slip are no longer necessary, thus making it possible to improve the quality of the product.

In addition, the use of coarse feldspars would allow considerable cost savings. Indeed, consider a continuous mill with a production of 20 t/h of dry mix that utilizes 50 % air-classified feldspar in the production of slips for unglazed porcellanato tile. In this case, using only feldspar in the rice grain form and adopting „MaxxMill" to achieve the additional fineness of grinding required could lead to savings in production costs of around EUR 600 000 per year.

Additionally it is to emphasize the very low additional space requirements due to the insertion of „MaxxMill" into the production line. Indeed „MaxxMill 5", with a production capacity of 4,5...6 t/h of dry mix and an 800 l grinding pan, occupies a total floor space of around 8 m^2. The „MaxxMill" can be placed direct on the floor and no special foundations are necessary.

In conclusion, the results obtained in this study clearly illustrate that the use of „MaxxMill" makes it possible to increase the energy efficiency of grinding systems presently in operation for the preparation of unglazed porcellanato tile mixes and also renders the final product more competitive.

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