OPTIMIZATION OF WET GRINDING BY APPLICATION OF AN INVERTER IN GRINDING MILLS

by G. Nassetti, C. Palmonari

CENTRO CERAMICO, Bologna

1. INTRODUCTION

In the past decade, electrical drives comprising an electric motor and an electronic converter for continuous setting of motor speed have been introduced in many machines and implemented in replacement of mechanical and oil-driven speed controllers.

Besides improving the accuracy of speed control, these drives also allow the implementation of flexible automated systems in production processes and provide substantial energy savings.

In the ceramics industry, an example of this application is the use of an inverter in discontinuous grinding mills, allowing mill speed changes during the grinding process of ceramic raw materials.

Grinding mills are machines which use energy from the motor to break down bonded materials, reducing them to an aqueous substance made up of very fine particles. Such results are achieved by overcoming the cohesive forces of the bonded material, although some of the exertion needed for this task dissipates in the form of heat through attrition and leakage from the inside of the mill and from the motor itself. Optimum grinding performance is accomplished when maximum power is achieved to overcome the cohesive forces of the material while a minimum is lost due to attrition or leakage.

In order to optimize operating conditions it is necessary to identify the mill's optimum speed, i.e. the speed at which greatest advantage can be taken of the grinding action of the balls: by grinding due to the cascading action of the grinding components and by attrition due to their reciprocal rotation.

It is obvious that in order to keep a constant speed throughout the entire grinding process, as has been done thus far since grinding mills are designed and built to maintain a specific fixed speed, a compromise has to be struck during the grinding process. Indeed, it is impossible to adapt the grinding action to the dimensions that the material takes on during the process.

Upon analysis of a grinding curve (Fig. 1), we can see that the process is broken down into three stages:

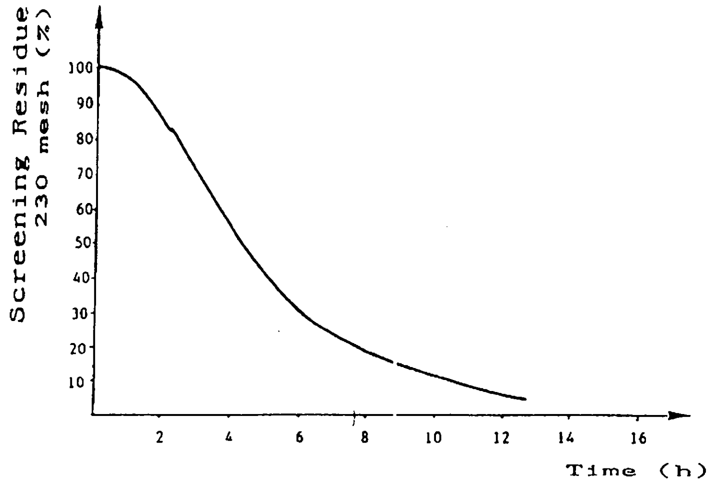

Fig. 1 - Behavior of the screening residue as a function of the grinding time

- An initial stage in which the screening residue, which indicates the degree of the material's breakdown, changes very slowly. In this stage, the prevailing action is the mixing of the material with the grinding components.

- An intermediate stage in which the screening residue decreases markedly during grinding. In this stage, grinding is the main action, and the breakdown of the material progresses noticeably.

- A final stage, in which the screening residue causes a significant decrease in the variation itself, tending asymptotically towards zero as the grinding time increases. During this stage the main grinding action is attrition, and refining of the material is achieved.

Therefore, changing the speed in order to break down the larger elements by grinding during the first stage and a friction action during the final stage, in order to refine the material, can increase the mill's output and save time and energy.

The main advantages to be had from applying an inverter to the discontinuous grinding mill are as follows:

- Gradual start-up of the mill.
- Connection of the motor by means of a rigid joint instead of a viscous joint.
- Ability to adapt grinding action to material dimensions during the course of the grinding process.

These advantages provide, in practice, the following benefits in terms of energy, installation and operation:

- Lower energy consumption.
- Decreased grinding time.
- Reduced wear of grinding components.
- Increased productivity.
- Reduced utilities bill by taking advantage of more convenient rates.
- Counterphase shift of mill motor.
- Greater availability of electrical power for other uses.
- Greater ease of installation.
- Reduced demands on mechanical transmission parts.

2. THE EXPERIMENTAL STAGE

With the purpose of quantifying some of the mentioned advantages, the Centro Ceramico di Bologna has conducted a series of tests in different production contexts. Special consideration was given to grinding of vitreous porcelain paste and single-fired whiteware.

Production of single-fired redware was excluded from testing for two reasons:

- Because the preparation of this paste by wetting is restricted to quick-fired earthenware products.

- Because the grinding times of these pastes in the grinding mill are substantially lower and, therefore, the application of the inverter is not as beneficial.

The application of the inverter was tested on large-scale (30,000-38,000 l) grinding mills and at different grinding torques, according to the nature and density of the grinding components and the mill lining.

The criterion adopted for testing was to conduct a series of grinding tests at varied speeds, using maximum rotation speed during the initial grinding stage and adopting a lower speed in the following stage. The speed ranged from 10 to 17 rpm, which is the range indicated by grinding theory for this type of mills.

Technological parameters for slips were given for every test, particularly screening residues and energy consumption of the mill.

It was also possible to identify the most convenient speed and the most appropriate time for speed change in view of optimizing the grinding process, thus reducing energy consumption and cycle time with respect to reference conditions.

3. RESULTS

The results are reported in two different production contexts, either in terms of paste or grinding torque.

In the case of vitreous porcelain paste grinding, tests were conducted on a mill with the following reference data:

Production:	23,900 kg of slip at 32.7% average humidity
Mill type:	OMS, capacity 30,000 l
Torque:	silica (grinding components) ; Alubit (lining)
Total revolutions:	15,500
Speed:	11.5 rpm
Grinding time:	22.5 h
Screening residue at 45 µm (ASTM 325 Mesh):	:2.5%

In the variable-speed grinding tests the best results were obtained following a speed curve (Fig. 2) in which, after gradual start-up of the mill, grinding took place first at 15 rpm for 9,000 revolutions and then at 10 rpm until collection of the screening residue.

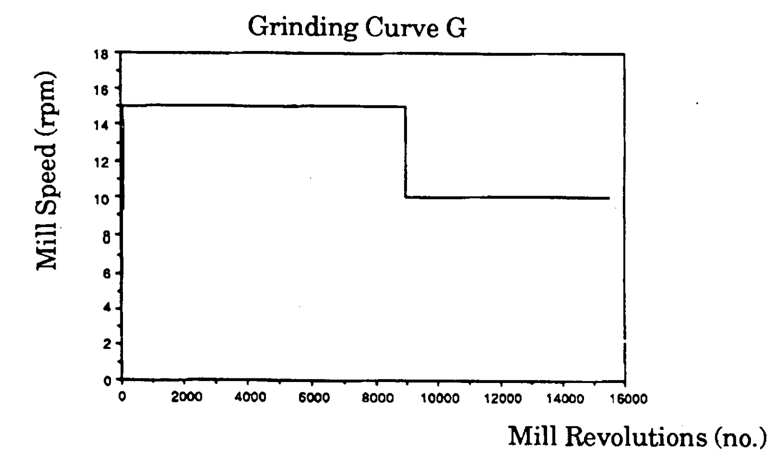

Fig. 2

Fig. 3 shows the evolution of the screening residue at 45 μm of the slip produced by the mill when operating at variable speed for the different testing conditions, according to the revolutions of the mill.

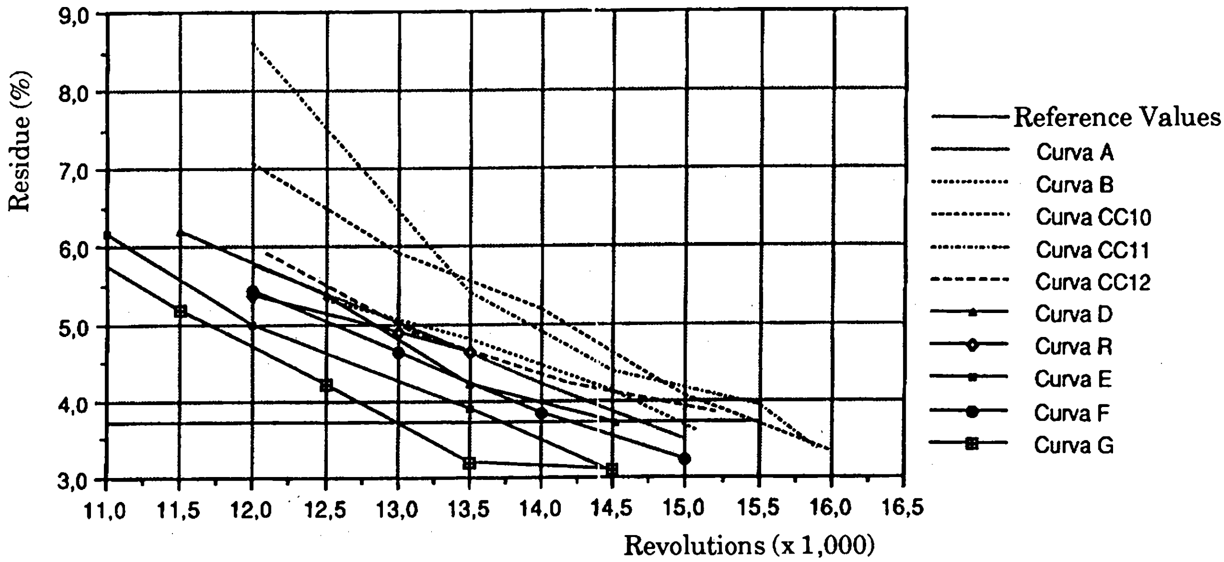

Fig. 3 - Evolution of the screening residue at 45 μm for the last revolutions of mill 7 (various grinding curves)

It can be seen in Fig. 3 that the test which provided the best results was the one conducted according to curve G, in which the screening residue was collected at 13,000 revolutions instead of 15,000 revolutions.

In Fig. 4, the evolution of residue was examined based on the energy absorbed by the mill instead of on number of revolutions completed.

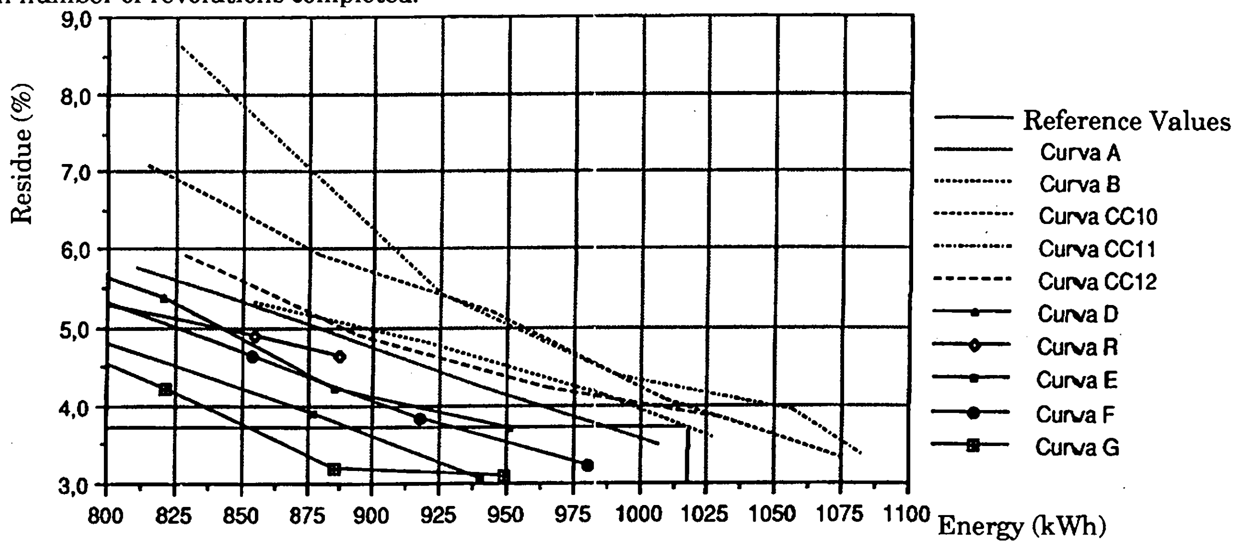

Fig. 4 - Evolution of the screening residue at 45 μm for the last revolutions of mill 7 (various grinding curves)

A perfect consistency can be observed between this graph and the preceding one. Collection of residue at a lower number of revolutions completed means improved energy management and, consequently, energy savings.

This test achieved a 25.3% reduction of grinding time (equivalent to 5h 40m) and a 16.2% decrease in absorbed energy (equalling 165 kWh) with respect to reference conditions. It is important to note that reduced time is consistent with energy savings, thus demonstrating that the application of variable speed optimizes the grinding process in grinding mills and consequently provides enhanced performance.

It should be noted that the results in terms of energy savings did not take into account the reduction of absorbed energy owing to the elimination of the viscous transmission joint, as this was not quantified in the experimentation. In other cases in which this factor was examined, the savings varied between 7% and 11%, depending on the mechanical conditions of the joint.

In the case of grinding of single-fired whiteware paste, tests were conducted on a mill with the following reference data:

Production:	20,000 kg of slip at 33% average humidity
Mill type:	ICF, capacity 32,500 l
Torque:	silica (grinding components) silica (lining)
Total revolutions:	8,000
Speed:	12 rpm
Grinding time:	11 h
Screening residue at 45 μm (ASTM 325 Mesh):	9.5%

In this case too, different grinding tests were conducted using the same criterion applied in the case of vitreous porcelain paste. The best results were also obtained with a speed curve (Fig. 5) similar to that of the vitreous porcelain: gradual start-up of the mill, speed of 10 rpm for the first 500 revolutions, 15 rpm for the following 4,500 revolutions, and 11 rpm up to collection of the screening residue.

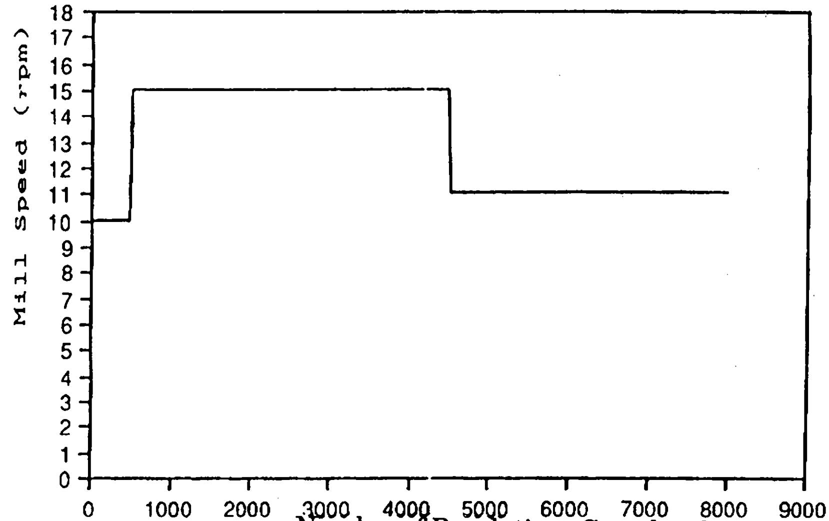

Fig. 5 - Single-fired whiteware: grinding test no. 1

With this speed curve the screening residue was obtained at 7,350 revolutions, instead of 8,000 revolutions (Fig. 6), with savings of 13.5% and 18% in time and energy, respectively.

In this case, energy savings take into account the elimination of the viscous transmission joint.

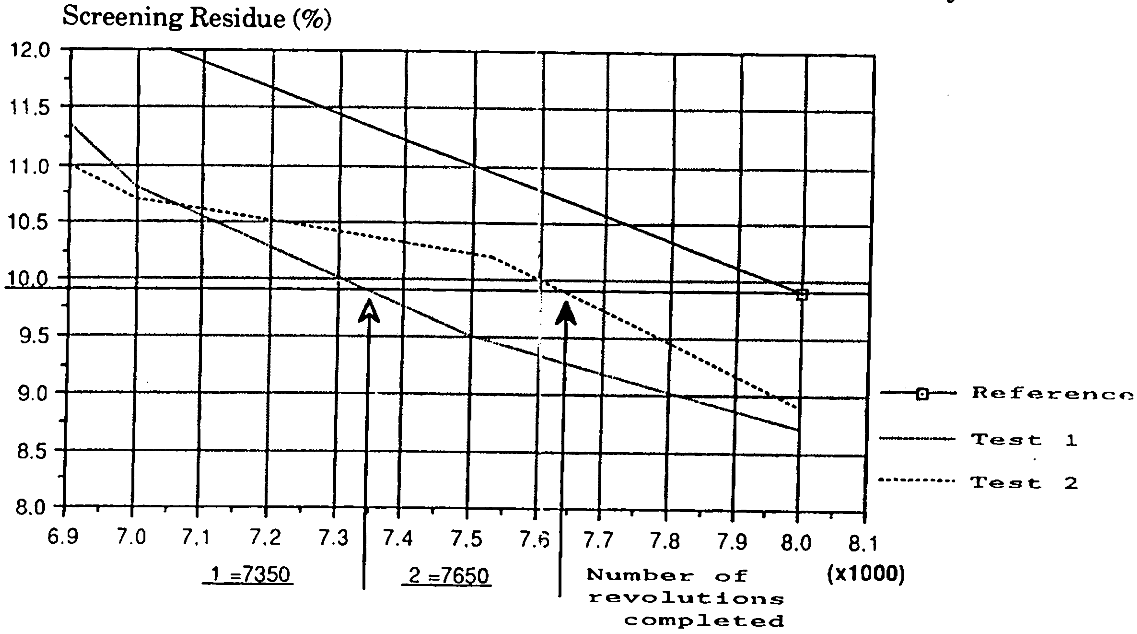

Fig. 6 - Single-fired whiteware: screening residue on a 45 μm Screen (325 mesh)

Other tests conducted following the same methodology in different production situations allowed us to pinpoint the range of variation of energy and time savings for vitreous porcelain and for single-fired whiteware. For vitreous porcelain, grinding time savings were quantified between 15% and 25% and energy savings were also between 15% and 25%, whereas in the case of the whiteware, time savings of up to 15% and energy savings between 10% and 20% were recorded. These variations depend primarily on the grinding torque and the material-grinding component load ratio.

4. CONCLUSIONS

In conclusion, it can be stated that the application of variable speed to the discontinuous grinding mill provides a flexible automated system for the grinding process and results in enhanced performance of the mill.

The main advantages found in such application are:

- **System Integration:** Being a D.C. converter, the inverter can be applied directly to the triphasic asynchronous motors usually equipped in these mills.

- **Flexibility:** The inverter provides flexibility to machines, like the discontinuous grinding mill, which by definition are rigid, thus optimizing operation in real production and operating situations.
  The flexibility of the system makes it possible to program more convenient speeds in order to achieve energy and time savings, although especially the latter, with respect to delivery requirements.

- **Energy Savings:** The optimization of the grinding curve means enhanced mill efficiency and, consequently, lower energy consumption.

- **Increased Productivity:** Reduced cycle time implies increased grinding productivity, allowing for greater production without having to increase the number of working mills.

- **Cost-Effectiveness, Operating Convenience and Enhanced Quality:** The reduction of cycle time can, in some cases, allow the adoption of lower-density grinding components (silica and Alubit alike), keeping delivery productivity within acceptable bounds and with substantial savings in terms of their cost, thus enhancing the product's competitive standing. In other cases it can provide greater grinding effectiveness, enhancing product quality without increasing grinding time and energy consumption, and, therefore, without increasing production costs.

NOTE:

The above text is a draft and not a final version. The authors reserve the right to make any modifications thereto which they may deem convenient in order to more completely update the contents thereof.