A New Grinding Process
HOROMILL®

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Abstract:

FCB has just developed a new mill, HOROMILL®, for grinding cement , raw meal and minerals. This new grinding process is designed for finish grinding and also for pregrinding. The energy saving is similar as roll press, roughly 30% to 50% in respect to the ball mill, but with a moderate circulating load and grinding pressure. After a research phase on a 1 t/h pilot plant, a first 25 t/h industrial plant was achieved in co-operation with Fratelli Buzzi at Trino, Italy. The performances and the cement quality, strength and workability, were checked on this industrial size.

1. Historical account on HOROMILL®

The development of the roll presses in pregrinding has shown the interest of compression grinding from the power consumption point of view with respect to the ball mill. The FCB Research Centre has carried out many works in this domain and has particularly studied the interest of this process in finish grinding. The results of these researches conducted on a pilot plant with a throughput of one tonne per hour can be summarised as follows :

- The compression grinding process leads to specific energy values markedly lower than those obtained in a ball mill, even under optimal conditions. The substitution ratios (ratio of the specific energy required by the ball mill to that required by the roll press at the same fineness) vary between 1.4 and 1.8 for cement. These figures obtained by means of the FCB-Index correspond to grinding energy values of ball mills under optimal conditions and therefore are minimum values. For industrial plants, the substitution ratios would rather be in the order of 1.6 - 2.0 in average, under assumption of an average efficiency of 0.9 with respect to the FCB-Index.
- The substitution ratio increases with the fineness roughly proportionally to the square root of the Blaine value ; on the other hand, the nip becomes more difficult and less stable and the circulating load increases proportionally to the fineness. It must be noted that the increase of the circulating load is accompanied by an important modification of the finished product size distribution curve.
- For reasons related to the nip dynamics, the grinding speed is limited. Close to this maximum speed, vibration problems are frequent.
- The grinding pressure is high so as to perform a maximum grinding work in only one pass and limit the circulating load, but does not always correspond to the optimal value. In general, grinding efficiency increases with pressure reduction (cements with limestone or pozzolana addition, cement raw mix). Furthermore, the use of high pressures causes lifetime and reliability problems.

Reflections and investigations were initiated to find another grinding process based on compression in order to keep the energy performance of this process, while grinding the material in several steps to prevent a too high circulating load and grinding pressure. The principle of a cylindrical shell driven in rotation on its horizontal axis, and one or several idle rolls seemed to be a possible solution. The point that seemed to be most difficult, was the control of the material circulation for which centrifugal force had to play an important role. The construction of a 1 t/h pilot plant gave birth to this new process.

At the beginning Fratelli Buzzi was interested in this new grinding idea and ready to do something if the idea was good. So FCB decided to construct a pilot mill in his Research Centre.

2. Description of the HOROMILL®

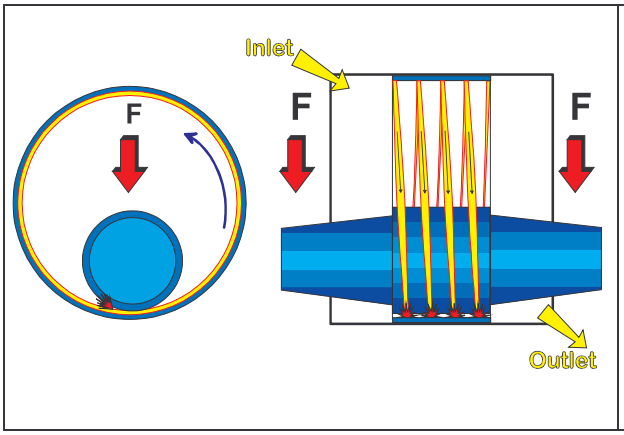

Figure 1 : HOROMILL® principle

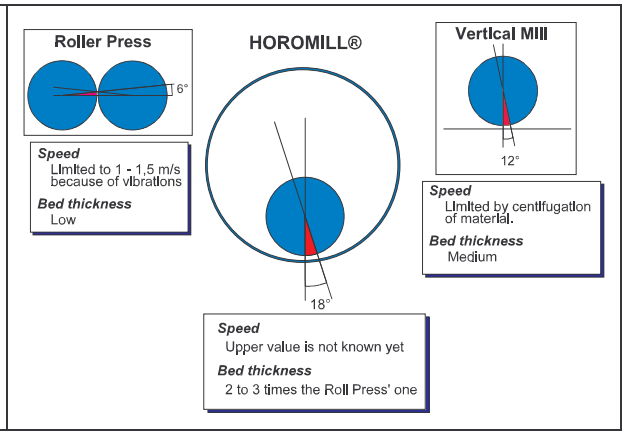

Figure 2 : Comparison of the angles of nip

For reasons of construction, feasibility and cost, the simplest configuration was selected, i.e. only one idle roller within a cylindrical shell. The shell is driven in rotation by a gear motor via a rim gear and a pinion. The grinding force is transmitted to the roller by hydraulic cylinders. Internals are provided to control the material circulation.

The main operational features of this mill can be described as follows.

The material advances regularly in the mill thanks to the combined effects of centrifugal force and adequate internals, and passes several times between the roller and the shell to be ground there. Grinding is thus achieved in several steps, which permits an important comminution work while operating at moderate pressure about four or five times lower than in the roll presses.

The conjugate concave and convex geometries of the grinding surfaces lead to angles of nip two or three times higher than in roll presses, which leads to a thicker ground layer and a more important grinding work. On principle, the grinding zone is very regularly fed, which ensures a maximum and stable nip of the material between the roll and the shell.

From the mechanical point of view, HOROMILL® combines proven elements from the ball mill (cylindrical shell on hydrodynamic shoes, drive gear rim) and elements akin to the press (roller, bearings) but with much lower grinding pressures.

3. A new grinding process

HOROMILL® is essentially designed for integral grinding in conjunction with the TSV Classifier, but can be quite integrated to a grinding circuit including a ball mill.

In order to develop and assess the performance of this new process, the pilot plant of the FCB Research Centre was arranged to operate with the roll press or with HOROMILL®.

The pilot HOROMILL® has the following technical data :

- installed power : 45 kW
- shell diameter : 800 mm
- separation circuit capacity up to 20 t/h
- finished product capacity up to 2.5 t/h
- possibility of varying the grinding pressure from 25% to 200% of the nominal pressure
- capability of drying up to 20% water

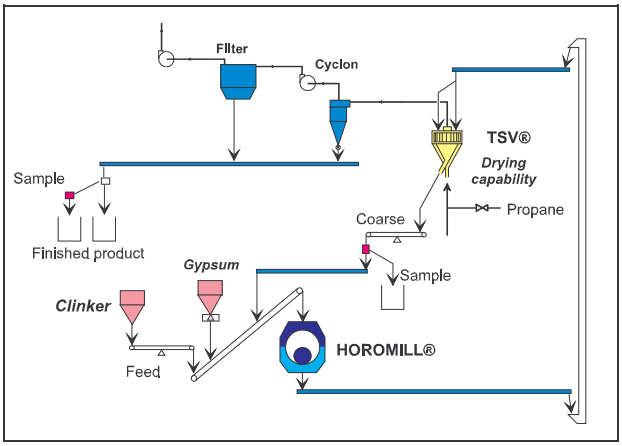

Figure 3 : Flow Sheet of FCB's pilot plant

The plant is fitted with sensors able to give all the characteristics of the circuit. The mill is fitted with a direct measurement of the mechanical torque in order to assess energy consumption with accuracy.

After the development phase of the machine, complete tests were conducted on raw mixes and different types of cement : Portland cement, cement with limestone or pozzolana. These results were compared with tests carried out on the roll press in integral grinding.

Finenesses from 3000 to 5000 Blaine for cements, and 15 % to 0.2 % rejects above 80 µm for raw mixes are tested.

For the cements, the conventional tests on mortar and concrete were carried out and compared with industrial results.

The results can be summarised as follows :

- For the cements :
  - substitution ratios vary from 1.3 to 1.75 depending on the settings. The size distribution curves show a course intermediate between the roll press and the ball mill results with however a very marked signature of the TSV for the coarse fraction (larger than d80). But the slope for the fines particles distribution can be adjusted with the setting of the circulating load.
  - at the same Blaine fineness, mortar and concrete strengths are higher than those obtained in ball mill and workability is equivalent.
- For the raw mixes :
  - substitution ratios vary from 1.5 to 2.2 depending on the settings.
  - very high finenesses at 80 µm are easily obtained.
  - water contents up to 20% were successfully tested in using the drying capability of the TSV classifier.

Pilot tests have confirmed the interest of this new process in comparison with the roll press and the ball mill :

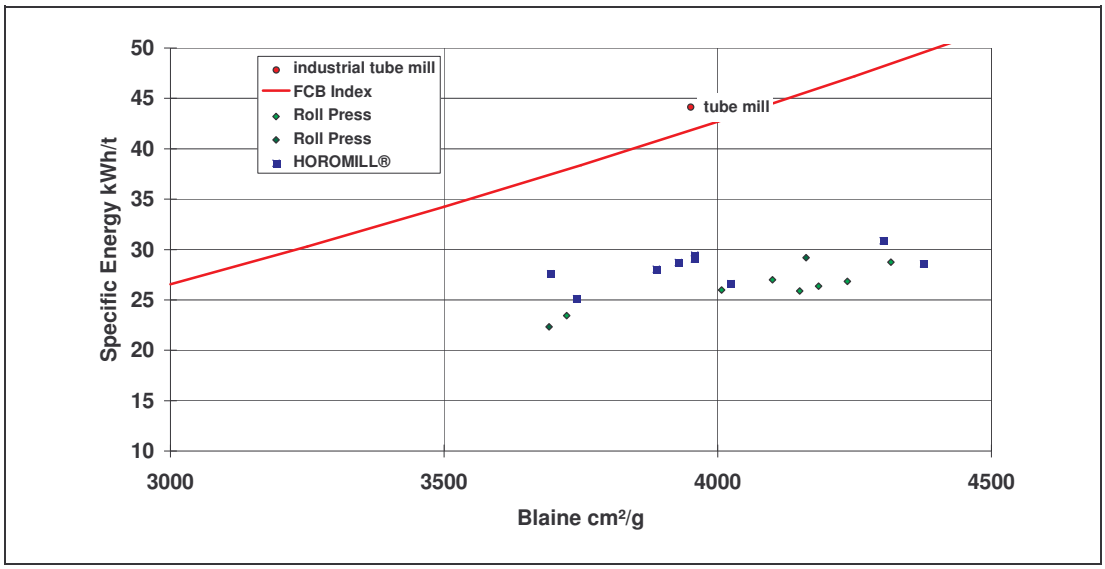

Figure 4 : CPA HP cement (92.5% clinker)

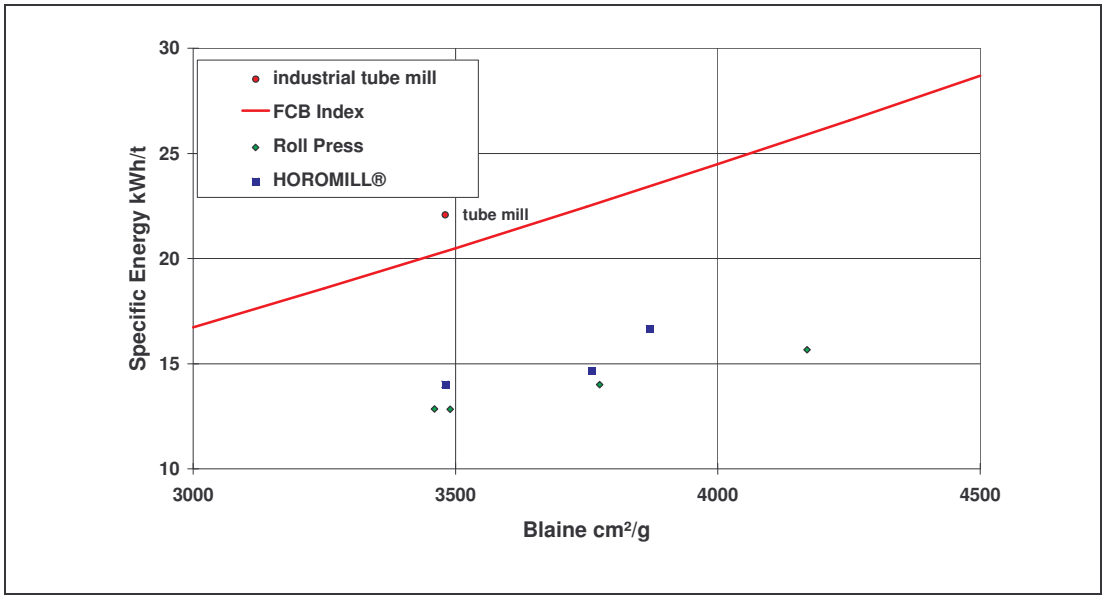

Figure 5 : CPJ 45 cement (18% limestone; clinker)

- Energy efficiency values are very close to those of the roll press or even higher for cement with a high addition ratio (unless the grinding pressure is considerably reduced in the press and the circulating load consequently increased).
- The grinding principle based on multiple compressions permits, for a same finished product, to vary the circulating load and to assess the corresponding effect on the size distribution curve and the performances (specific energy, cement quality, ...). With this additional degree of freedom, HOROMILL® is, in closed-circuit grinding, more akin to the ball mill than to the press. Therefore, even for very fine cements, it is possible to adopt a reasonable circulating load while using a limited grinding pressure.

- HOROMILL® operation is very stable and little sensitive to the raw material particle size distribution or to the rotational speed.

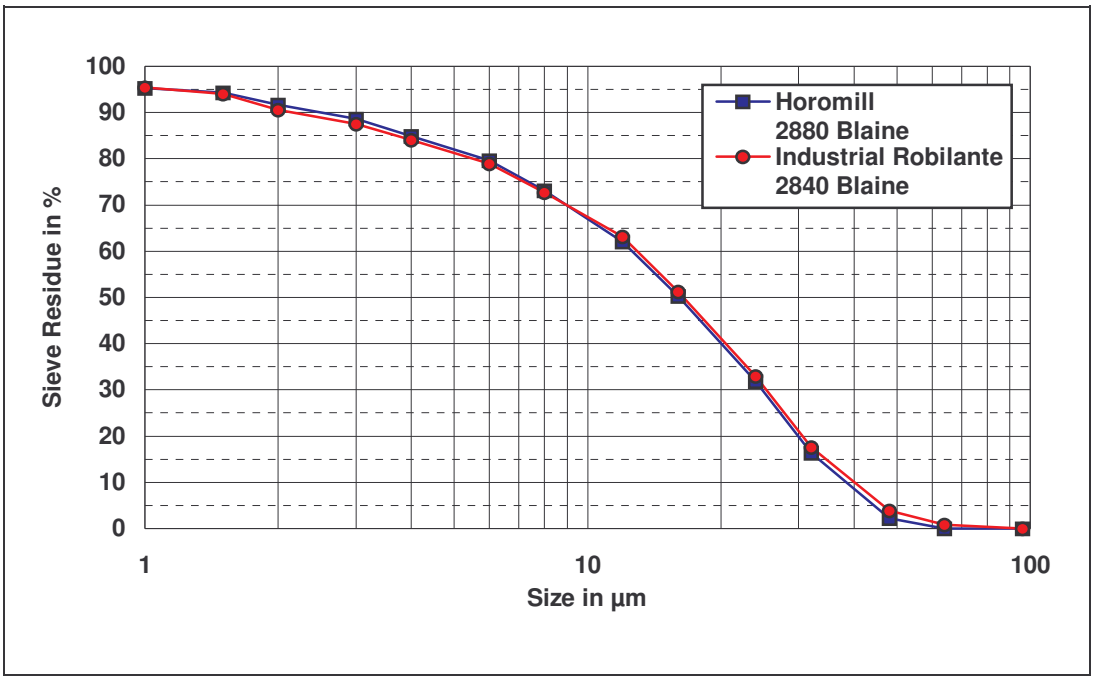

Figure 6 : Comparison between grain size distribution of HOROMILL®'s cement and the equivalent ball mill one's

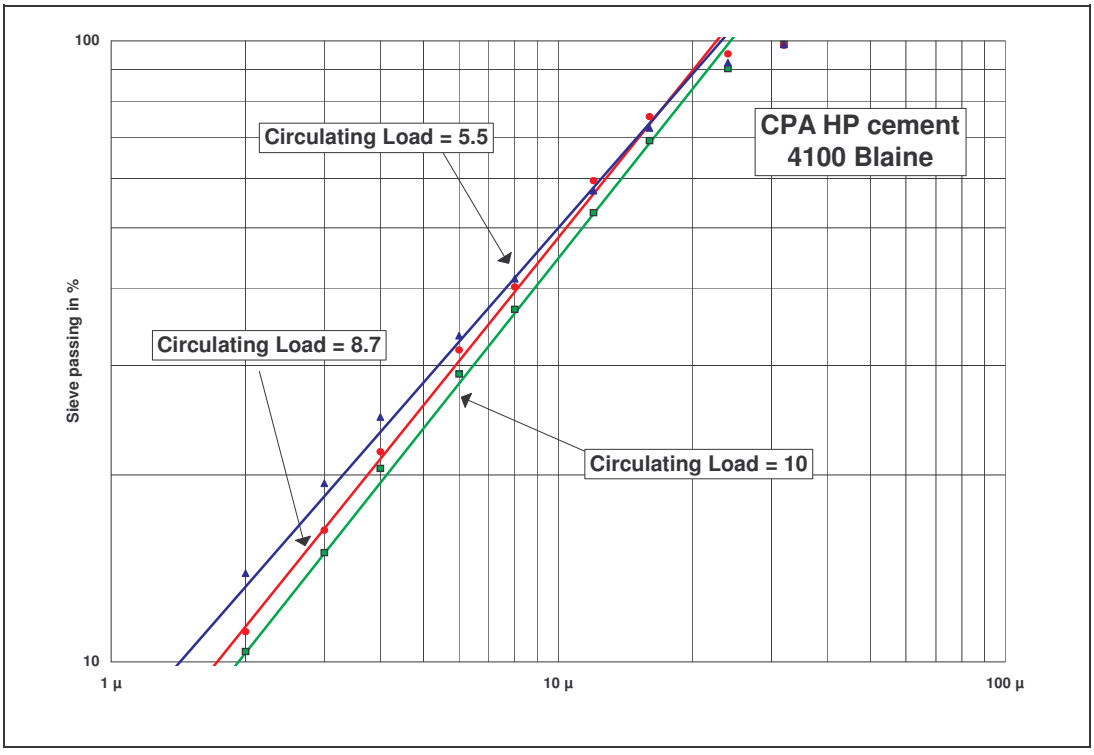

Figure 7 : Circulating load influence on grain size distribution slope (Gaudin-Schuhmann Diagram)

4. The first industrial achievement

4.1 The first HOROMILL® grinding plant

The first industrial plant was performed in co-operation with Fratelli Buzzi in the Plant of Trino, Italy. A financial aid from the EEC as part of the Thermie Programme made this achievement easier.

The design and construction of this new plant began in August 1992 and the mill start up took place on the 10 September 1993.

The main features of the grinding plant are as follows :

- HOROMILL® :
  - Installed power : 600 kW at variable speed
  - Diameter : 2200 mm
- Circuit :
  - nominal rate in CP42.5R production : 25 t/h at 3200 Blaine
  - nominal circulating load : 140 t/h
  - TSV classifier.

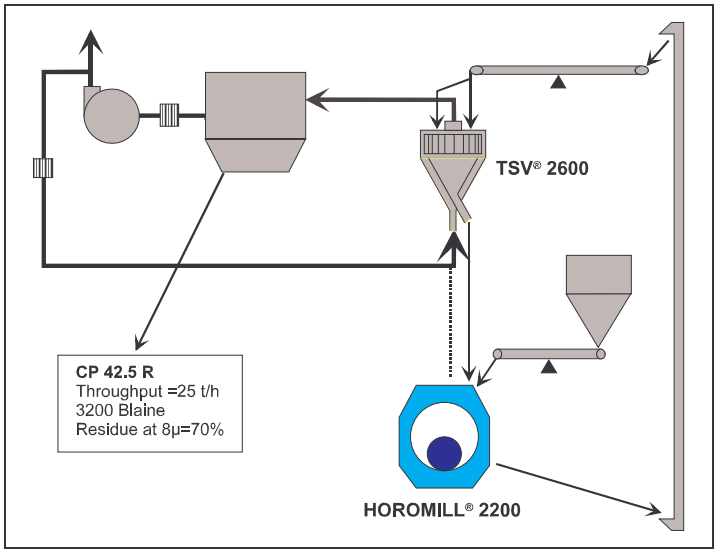

Figure 8 : Flow Sheet of Trino's HOROMILL® plant

Installed beside existing grinding plants, HOROMILL® is intended to work also in pregrinding, hybrid grinding or in finish grinding.

The circuit simplicity as well as the mill and plant compactness are noteworthy. The circuit includes an elevator, a conveyor to the TSV classifier, a finished product recovery filter at the TSV outlet and an exhauster. The rejects from the TSV classifier are returned by gravity to the mill inlet.

The mill is very compact : 2200 mm shell diameter by 2000 mm long which leads to an overall space requirement of 3800 by 3800 without the drive unit. For the same capacity, a 900 kW ball mill 2800 mm diameter by 9500 mm grinding length should be installed, i.e. a space requirement of 4200 x 14000 mm for the ball mill alone without the drive unit.

4.2 The first operation results

From the very first hours of operation, the mill reached its nominal throughput with performance beyond any expectations. The mill operation stability is spectacular : the circuit rises to its nominal regime in 5 - 10 minutes and the circulating load keeps constant to within 2 t/h ! This is due to the low material quantity in the circuit ; the response time is 50 seconds. Of course this stability leads to a very high regularity of the finished product. A fully automatic operation has been easily developed, including the mill stop and start up.

The dynamic behaviour of the machine is very satisfactory : no vibration in operation or during transient phases.

The first production results achieved in the manufacture of Portland Cement CP42.5R are :

- 3200 Blaine fineness (selected identical to the present production in ball mill)
- finished product throughput : 25 t/h
- motor shaft power : 400 kW i.e. 16 kWh/t

the corresponding substitution ratio with respect to the FCB-Index is 1.55, but exceeds 2.0 with respect to the existing open circuit ball mill (~ 31 kWh/t motor shaft power).

The quality of the produced cements has been tested and compared with that obtained in ball mill :

- concrete workabilities are equivalent.
- mortar and concrete strengths are always higher.

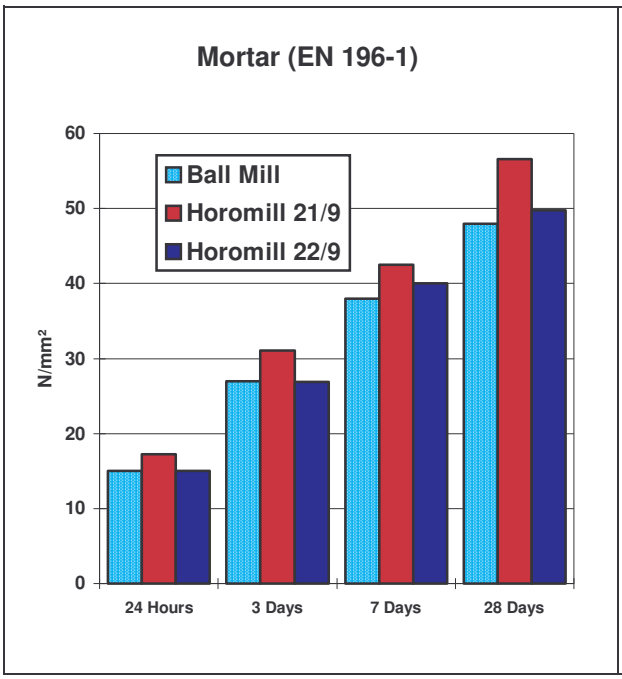

Figure 9 : Compressive strength on mortar

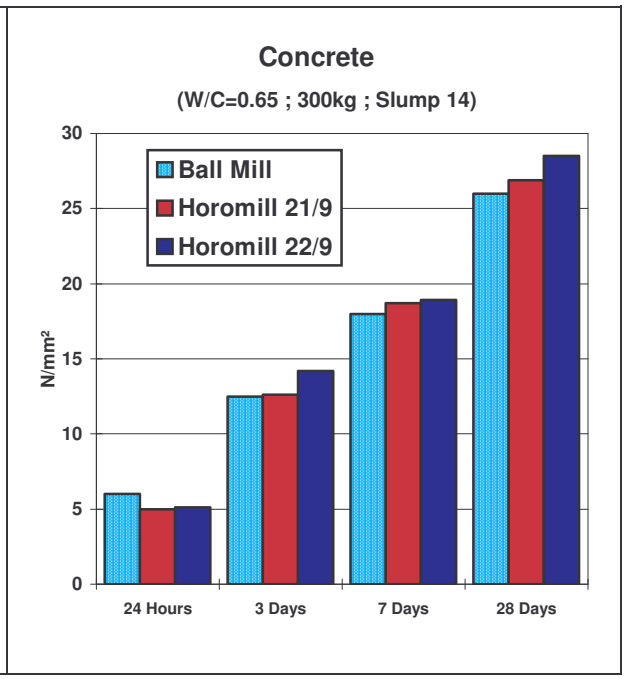

Figure 10 : Compressive strength on concrete

These first operational results correspond to a thousand hours of operation and of course call for a confirmation by longer operation times.

5. Industrial prospects

The comparison of the HOROMILL® plant data with the conventional processes seems to be particularly interesting :

With respect to the ball mill :

- energy saving of 30 - 50 %
- very compact plant and mill ; for the same capacity, HOROMILL® has a diameter slightly smaller than a ball mill, but is three times shorter.
- simplicity, easy operation and regular production due to very short residence time and response time.
- negligible pollution caused by wear of grinding parts.

With respect to the roll press :

- designed for integral grinding ; regular operation, no vibration.
- circulating load is smaller, and adjustable depending on the production and quality objectives.
- the moderate grinding pressure ensures a long lifetime of the wear parts and mechanical reliability, but also leads to a better efficiency for cements with additive.

6. Conclusions

A new grinding process, the HOROPROCESS, has entered into industrial production in the Fratelli Buzzi cement works at Trino, Italy. The first results achieved in cement CP42.5R are very encouraging and allow to expect energy saving by 40 % compared with the ball mill ; furthermore, they confirm the results obtained on the 1 t/h pilot mill in the FCB Research Centre.

The grinding process based on multiple compressions gives the machine a high stability but also permits to adjust the circulating load in compliance with the quality objectives.

Many tests remain to be conducted to state precisely and optimise the HOROMILL® performance.

The use of a moderate grinding pressure allows to expect a very good mechanical behaviour of the machine.

A complete range of mills is already being designed with powers up to 4000 kW (200 t/h ordinary cement).