THE ULTIMATE SOLUTION FOR THE DRY PREPARATION OF THE CERAMIC BODY

Lorenzo Battaglioli

LB Officine Meccaniche S.p.A. - Via Pedemontana 166 - 41042 Fiorano Modenese – ITALY

ABSTRACT

The most important stage in ceramic body preparation for pressing is granulation. Granulation plays a key role in providing the ground material with flowability, facilitating loading of the press die, and promoting deaeration during the pressing process.

The globally accepted standard is spray dry granulation and most ceramic industries in the world have suitable plants for processing this material.

The long experience of LB OFFICINE MECCANICHE and its continuous research in the field of dry body preparation, applied to the ceramic industry, have led the company to innovate the granulation process in order to obtain a granulate with rheological characteristics comparable to those of spray-dried powder.

INTRODUCTION

In the last two years, the dry body preparation technology has taken a further step forward, presenting a newly patented system: with the new system it is possible to produce all types of tiles, from red body to white body tiles, from class BIII to class BIa, and even glazed porcelain stoneware slabs. This technology allows maximum plant flexibility in producing granulated mixtures and guarantees the possibility of producing granulometries suitable for all press loading systems.

The development of granulation technology concerns the central part of the granulation process: the main process machines remain the granulator and the fluid bed dryer. The selector placed between granulation and drying ensures that only the semi-finished product with the correct particle size distribution (PSD) is sent to the drying process. This allows for greater energy efficiency and full control over the particle size distribution of the granulated material: it is possible to switch from relatively fine particle sizes, indicated for replacing the classic moistened dry ground powder, to particle size distributions without a fine fraction, indicated for replicating the same flowability as that of spray-dried powder, guaranteeing the workability of the granulate with standard pressing parameters.

Types of semi-finished product sent for pressing and the related finished product:

- Moistened dry-milled body (e.g. South American red body, single-fired tiles): the evolution of ceramic production moves towards products with lower water absorption and increasingly larger formats. The new dry body preparation technology, compared to the classic moistened dry ground product, allows obtainment of more finely ground powder, lower water absorption, greater mechanical resistance and better surface quality. Furthermore, fine granulation provides the powder with better flowability, thus optimizing die loading and the pressing process (more homogeneous press loading, shorter deaeration times, higher pressing speed, and possibility of increasing finished product size), while maintaining the same smooth surface after pressing.

- Spray-dried wet-milled body (monoporosa, sintered single firing, porcelain tiles): the new dry body preparation guarantees the same fineness of grinding of the body mixture, in order to obtain the same reactivity during the firing process and enables production of a granulated powder with the same flowability as that of spray-dried powder.

The biggest difference between spray-dried granules and dry preparation granules is that the latter consist of "full" granules, formed by growth. Spray-dried granules, on the other hand, are made up of "hollow" granules, formed by the evaporation of water from the slip drops (*Figure 1*).

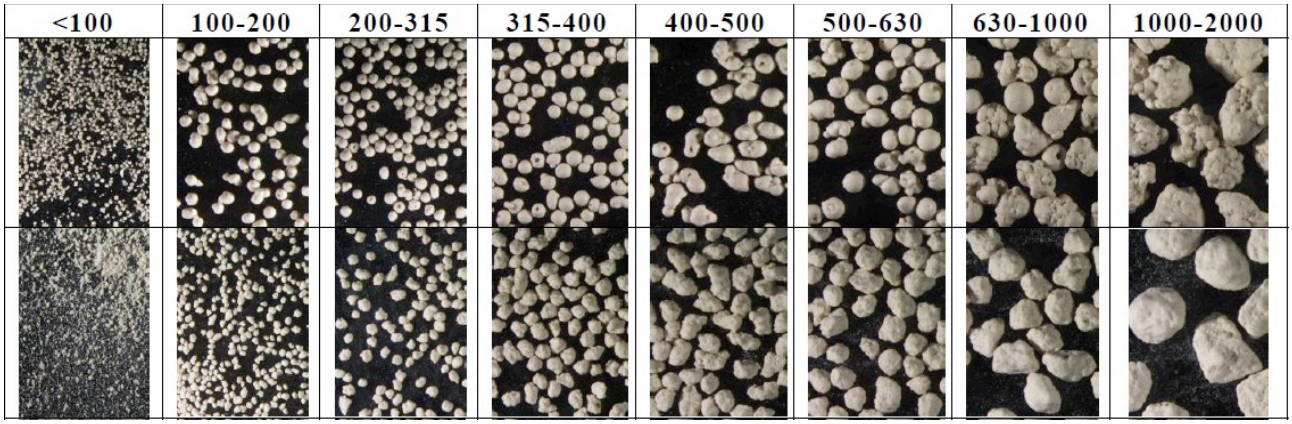

Figure 1 *– above images of spray-dried granules and below images of dry granules*

The flow chart of the new dry body preparation is shown in *Figure 2*.

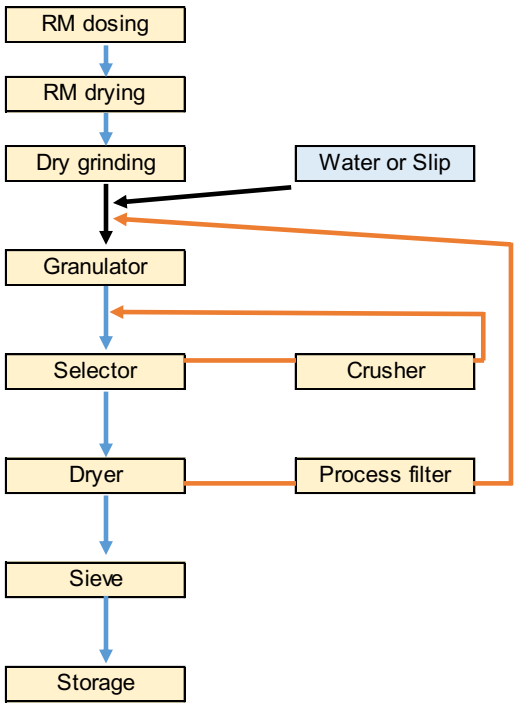

Figure 2 *– flow chart of dry body preparation*

This article presents two studies, carried out by our laboratory, on two diametrically opposed types of products. They show that the new system solution can provide technical and technological answers to solve problems and/or optimize the production of different types of tiles.

Two recent experiments carried out with a granulated body: in one case, aimed at optimizing production of red body single-fired tiles and, in the other, at producing glazed porcelain tiles with the dry technology, are described below.

EXPERIMENTAL

All the processes required to produce the granulated mixtures were carried out in the pilot plant located in the laboratory, composed of a ball mill (*Figure 3*), vertical roller mill (*Figure 4*), and granulation plant (*Figure 5*), which enables replication of the semi-finished products produced by an industrial plant.

***Figure 3** – ball mill*

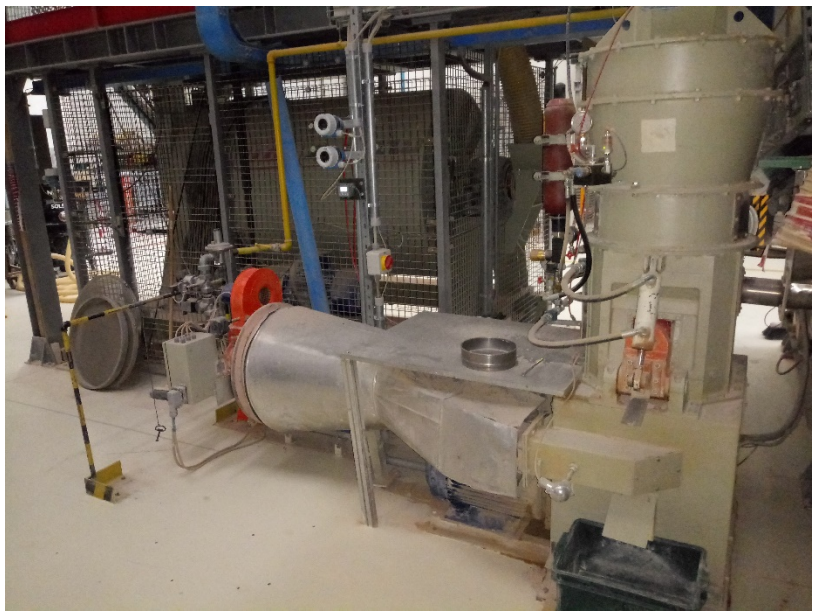

***Figure 4** – vertical roller mill*

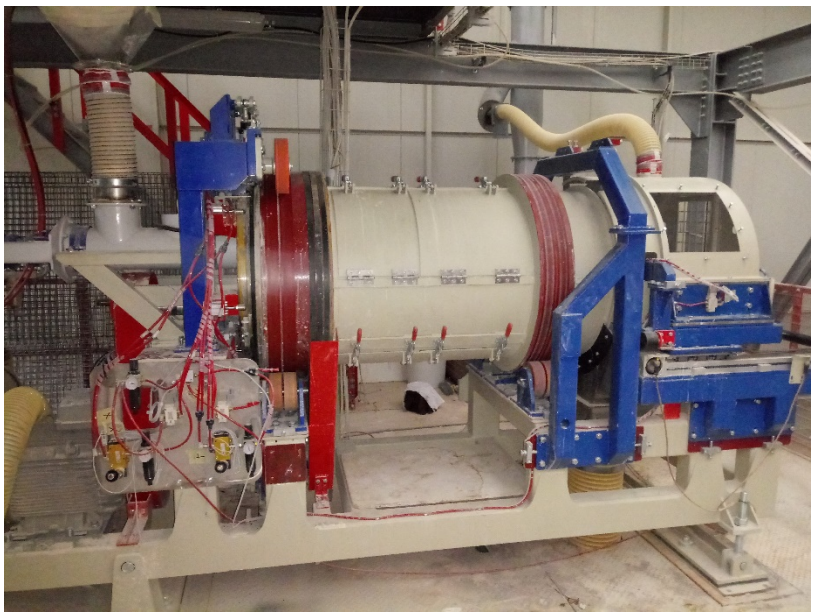

***Figure 5** – HGT granulator*

***Figure 6** – flowability funnel*

Flowability is determined by measuring the emptying time of the granulate from a stainless steel funnel with a capacity of 2361,5 cm^3 (*Figure 6*).

Red body single-firing tiles – BIIb

For a South American customer, a body preparation test was carried out using the new system (dry grinding and granulation), producing two different grain size distributions: a coarse one with which to carry out tests on large formats and a finer one with which to replace the moistened dry powder obtained in current production.

The raw materials mixture was ground in a lab-scale vertical roller mill, obtaining the same grain size as that resulting from the customer's industrial dry and wet grinding facilities (*Figure 7*).

INDUSTRIAL WET GRINDING	INDUSTRIAL DRY GRINDING	PILOT PLANT DRY GRINDING
D [3;2] 6,60 µm	**D [3;2]** 7,54 µm	**D [3;2]** 7,04 µm
D [4;3] 20,0 µm	**D [4;3]** 25,2 µm	**D [4;3]** 19,5 µm
Dv (10) 2,58 µm	**Dv (10)** 2,88 µm	**Dv (10)** 2,85 µm
Dv (50) 12,6 µm	**Dv (50)** 14,2 µm	**Dv (50)** 11,5 µm
Dv (80) 35,6 µm	**Dv (80)** 43,2 µm	**Dv (80)** 34,7 µm
Dv (90) 49,3 µm	**Dv (90)** 65,6 µm	**Dv (90)** 48,9 µm
Dv (97) 67,0 µm	**Dv (97)** 97,3 µm	**Dv (97)** 66,6 µm

Figure 7 *– red body PSD after grinding, industrial vs pilot plant*

With the dry ground material in the pilot plant, granulates with two different particle size distributions (PSDs) were produced, one coarse to replicate the flowability of the spray-dried material and the other with finer particle size to replace the moistened powder.

In both cases, the resulting granulate was pressed in parallel with the industrial mixtures in an industrial press with a 640x640 mm die. The result was an improvement in the technological characteristics, both before and after firing.

Figure 8 shows the grain size distributions of the granulates and the results of the technological characterizations of the red body tiles.

	spray dry powder	coarse granulate	
Moisture	6,8	7,60	%
Flowability	6,1	5,70	s
PSD			
1000 um	0,4	0,0	%
710 um	0,1	0,9	%
500 um	24,7	38,9	%
250 um	50,9	41,1	%
125 um	18,9	16,8	%
63 um	4,2	2,0	%
< 63 um	0,8	0,3	%
Expansion	0,50	0,12	%
Comp. Ratio	2,0	2,0	
Tile size	60x60		cm
Forming Pres	305	305	kg/cm^2
Green MOR	0,95	1,31	N/mm^2
Dry MOR	2,77	3,29	N/mm^2
Firing temp	1110/1120		°C
Firing cycle	41		min
Water abs	9,8	8,6	%
Shrinkage	2,8	2,5	%
MOR	35,5	36,7	N/mm^2

	moistened powder	fine granulate	
Moisture	7,5	8,1	%
Flowability	X	21,5	s
PSD			
1000 um	2,50	0,1	%
710 um	3,20	0,3	%
500 um	7,00	3,7	%
250 um	10,30	15,9	%
125 um	9,90	20,5	%
63 um	17,60	33,6	%
< 63 um	49,50	25,9	%
Expansion	0,50	0,12	%
Comp. Ratio	2,8	2,0	
HR	1,36	1,21	
Tile size	60x60		cm
Forming Pres	305	305	kg/cm^2
Green MOR	1,01	1,32	N/mm^2
Dry MOR	2,98	3,49	N/mm^2
Firing temp	1110/1130		°C
Firing cycle	28		min
Water abs	9,3	8,4	%
Shrinkage	2,3	2,0	%
MOR	31,2	32,8	N/mm^2

Figure 8 *- PSD of the granulate and technological characterization results*

A pressing test was conducted with the coarse granulate for the production of large slabs. The granulate was loaded correctly onto the feeding belt and forming took place without any problems. The cutting, drying and firing stages were carried out without any problems (*Figure 9 to 13*).

Figure 9 *- granules loaded onto the feeding*

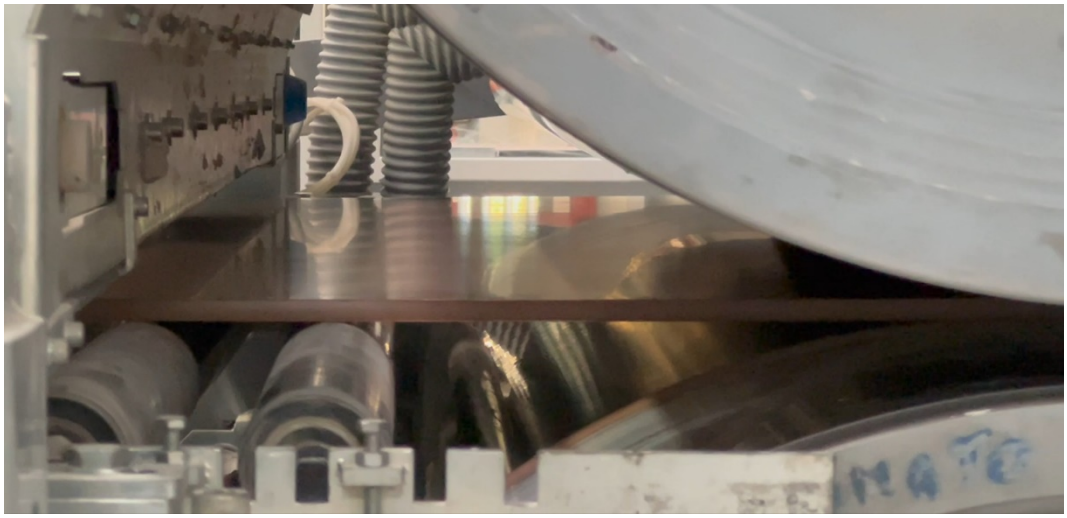

Figure 10 *- compacted slab exiting the machine*

Figure 11 *- slab on the cutting belt*

Figure 12 *- slab at the dryer inlet*

Figure 13 *– fired slab*

Glazed porcelain tiles – BIa

With regard to the test on red body tiles, in this case the customer also sent the raw materials mixture. The body mixture was dry ground in a ball mill. The particle size distribution resulting from dry milling was kept slightly finer than that obtained from wet milling (*Figure 14*).

INDUSTRIAL WET GRINDING	PILOT PLANT DRY GRINDING
D [3;2] 7,02 µm	**D [3;2]** 6,01 µm
D [4;3] 18,9 µm	**D [4;3]** 12,8 µm
Dv (10) 2,88 µm	**Dv (10)** 2,80 µm
Dv (50) 11,5 µm	**Dv (50)** 7,87 µm
Dv (80) 30,3 µm	**Dv (80)** 16,5 µm
Dv (90) 45,6 µm	**Dv (90)** 26,2 µm
Dv (97) 71,7 µm	**Dv (97)** 58,7 µm

Figure 14 *– porcelain body PSD after grinding, industrial vs pilot*

The ground mixture was granulated, to obtain a granulate with high flowability.

The granulate produced was pressed in parallel with the industrial spray-dried granules in an industrial press with a 640x640 mm die. The results of the characterization demonstrate that, with dry preparation, it is possible to produce tiles with the same characteristics as the porcelain tiles produced by wet body preparation.

Figure 15 shows the grain size distributions of the granulates and the results of the technological characterizations on the red body tiles.

	spray dry powder	coarse granulate	
Moisture	6,15	6,60	%
Flowability	6,3	5,90	s
PSD			
1000 um	0,3	0,0	%
710 um	1,3	0,6	%
500 um	17,4	34,7	%
250 um	62,2	44,7	%
125 um	14,8	16,0	%
63 um	3,9	3,5	%
< 63 um	0,1	0,5	%

Tile size	60x60		cm
Forming Pres	432	432	kg/cm^2
Green MOR	1,10	0,90	N/mm^2
Dry MOR	2,50	2,40	N/mm^2
Firing temp	1215/1225		°C
Firing cycle	48		min
Water abs	0,07	0,06	%
Shrinkage	6,8	6,9	%
MOR	44,8	45,1	N/mm^2

Figure 15 *– PSD of the granulate and technological characterization results*

The granulate produced was also used to press 600x1200 mm tiles (*Figure 16-17*), 150x900 mm tiles (*Figure 18-19*) and 1200x2400 mm slabs, from which 1200x1200 mm tiles were obtained (*Figure 20*).

Figure 16 *– 600x1200 mm pressed tile*

Figure 17 *– 600x1200 mm fired tile*

Figure 18 *– 150x900 mm pressed*

Figure 19 *– 150x900 mm fired tiles*

Figure 20 *– glazed 1200x1200 mm pressed tile obtained by cutting a 1200x3600 mm*

CONCLUSIONS

This new granulation process, a development of Migratech, allows obtainment of granulates that can optimize production with traditional dry grinding (e.g., red body tiles) and even replace the spray-dried material in the production of glazed porcelain tiles. The objective of improving the technological characteristics of the powders was achieved, approaching the rheological and compaction properties of spray-dried powders. This result undoubtedly represents a step forward in terms of powder properties.

This new technology proves to be versatile, enabling production of granulates with different particle size distributions in order to adapt to different production realities.

Furthermore, compared to wet preparation, it allows significant savings in energy and resources. The advantages of this technology are as follows:

- the possibility of obtaining substantial savings in thermal energy; the amount of water to be evaporated is less than that evaporated in the spray-drying process (65÷70% saving in thermal energy);
- the possibility of obtaining significant savings in water resources, up to (75%);
- the possibility of obtaining significant savings in grinding additive (from 70% to 100%);
- the possibility of replicating the flowability of spray-dried powders, ensuring the workability of the granulate with standard pressing parameters;
- the possibility of using heat recovered from other thermal processes or from cogeneration plants.

REFERENCES

[1] F.G. Melchiades, A.O. Boschi. "Study of the feasibility of producing porcelain tiles by the dry route." CFI-Ceramic Forum International 87 (2010) 43-49.
[2] G. Nassetti, G. Timellini. "Granulation of powders for whitebody ceramic tiles." Ceram. Eng. Sci. Proc. 12 (1991) 328-342.
[3] G. Nassetti, C. Palmonari. "Dry fine grinding and granulation vs wet grinding and spray drying in the preparation of a redware mix for fast-single-fired vitrified tile." Ceram. Eng. Sci. Proc. 14 (1993) 15-24.
[4] R. Soldati, C. Zanelli, G. Guarini, S. Fazio, M.C. Bignozzi, M. Dondi. "Characteristics and rheological behaviour of spray-dried powders for porcelain stoneware slabs." J. Eur. Ceram. Soc. 38 (2018) 4118-4126.
[5] R. Soldati, C. Zanelli, G. Guarini, A. Piancastelli, C. Melandri, S. Fazio, M.C. Bignozzi, M. Dondi. "Pore evolution and compaction behaviour of spray-dried bodies for porcelain stoneware slabs." J. Eur. Ceram. Soc. 38 (2018) 4127-4136.
[6] R. Soldati, C. Zanelli, G. Guarini, G. Cavani, L. Battaglioli, M. Dondi. "Novel micro-granulates for porcelain stoneware tiles: preliminary data on powder rheology and compaction." Qualicer, Castellón, Spain (2020).
[7] G. Cavani, L. Battaglioli. "Migratech 4.0 microgranulation technology for the production of large-size slabs." Ceramic World Review 129 (2018) 132-135.
[8] Z. Shu, J. Zhou, Y.X. Wang. "A novel approach of preparing press-powders for cleaner production of ceramic tiles." Journal of Cleaner Production 18 (2010) 1045–1051.
[9] Z. Shu, J. Garcia-Ten, E. Monfort, J.L. Amoros, J. Zhou, Y.X. Wang. "Cleaner production of porcelain tile powders. Granule and green compact characterization." Ceramics International 38 (2012) 517–526.
[10] F.G. Melchiades, L.R. dos Santos, S. Nastri, A.P. Leite, A.O. Boschi. "Reducing the yield stress of granules prepared by the dry route for the fabrication of porcelain tiles." Qualicer, Castellón, Spain (2012).
[11] F.G. Melchiades, L.R. dos Santos, S. Nastri, A.O. Boschi. "Influence of the nature of the granules on porcelain tile manufacture." Qualicer, Castellón, Spain (2012).
[12] C. Gil, D. Silvestre, J. Piquer, J. García-Ten, F. Quereda, M.J. Vicente. "Preparation of porcelain tile granulates by more environmentally sustainable processes." Bol. Soc. Esp. Cerám. V. 51 (2012) 67-74.
[13] F.G. Melchiades, L.R. dos Santos, S. Nastri, E. Cabral, A.O. Boschi. "Viabilidade da Fabricação de Porcelanatos por Via Seca a Partir de Massas de Cor de Queima Clara. Parte II: Condições de Granulação da Massa." Cerâmica Industrial 17 (2012) 5-6.
[14] F.G. Melchiades, L.R. dos Santos, S. Nastri, A.O. Boschi. "Comparison between spray-dried and dry granulated powders in the fabrication of porcelain tiles." Interceram 61 (2012) 254-258.