OBTAINMENT OF CERAMIC TILES USING SUSTAINABLE GRANULATION SYSTEMS

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1. INTRODUCTION

The most widely used process in manufacturing ceramic tile bodies in Europe is the so-called "wet" method, which consists of milling a mixture of raw materials in water and then spray drying the resulting slurry to obtain a spherical granulate. In this study, the technical feasibility was investigated of obtaining granulates by an alternative process, in which the raw materials were dry milled and subsequently granulated. The study shows that the "dry" process would significantly reduce the energy costs and environmental impact with respect to those of the "wet" process [1][2].

2. EXPERIMENTAL

The feasibility study was conducted for the following types of ceramic tiles: red-firing stoneware tile (hereafter referenced GR), red-firing earthenware tile (AR), and white-firing earthenware tile (AB) in view of the differences existing in the types of raw materials used in each of these and of the different behaviour of these mixtures of raw materials in the ceramic tile manufacturing process.

The behaviour of each of these types of tile in pressing and in firing was compared, as were the unfired and fired mechanical properties of an industrially obtained spray-dried powder (hereafter referenced spray-dried powder GR, spray-dried powder AR, and spray-dried powder AB) and of the powder granulate obtained on a laboratory scale using the same raw materials (hereafter referenced granulate GR, granulate AR, and granulate AB), adjusting the process variables when this was necessary. Finally, granulates of the different studied compositions were prepared on an industrial scale, from which tiles were fabricated in an industrial plant.

3. RESULTS

Figures 1 and 2 show the different morphology and porosity of the new granules compared with those of current spray-dried powders (lower porosity and sphericity of the granulates obtained by the dry method [1][2]).

The different microstructure of the granulates obtained by the dry method with regard to that of the spray-dried powders in turn modified unfired tile microstructure and, consequently, fired tile microstructure. Figures 3 and 4 show the microstructure of fired test pieces obtained with the spray-dried powder and with the granulate of the red-firing stoneware tile. It can be observed that for this composition, as well as for the earthenware tile compositions, though the test pieces with the new granulates were less porous, they exhibited larger pores because the granules did not completely deform.

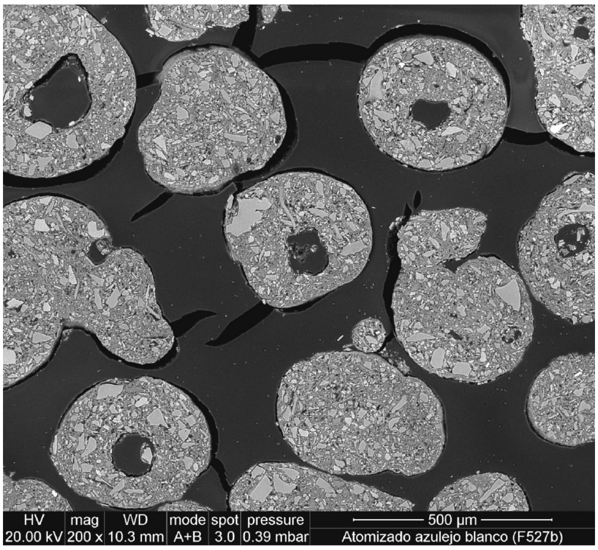

Figure 1. Microstructure of spray-dried powder AB.

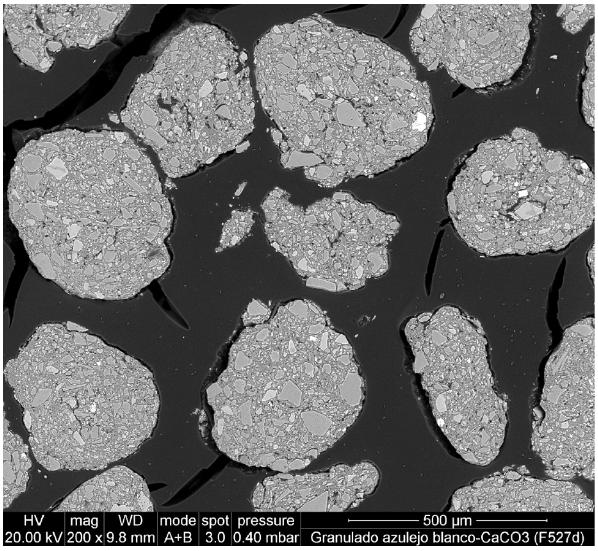

Figure 2. Microstructure of granulate AB.

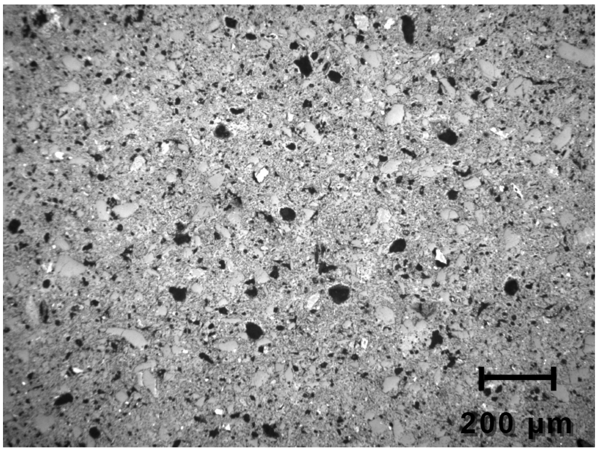

Figure 3. Microstructure of the fired piece formed with spray-dried powder GR.

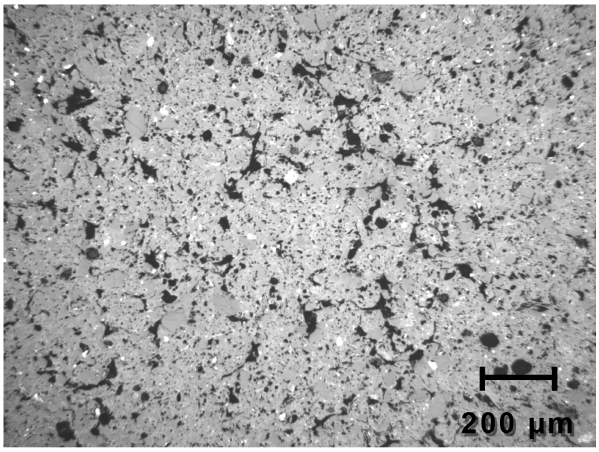

Figure 4. Microstructure of the fired piece formed with granulate GR.

The presence of large pores in the test pieces formed with the granulates led to slightly lower dry and fired mechanical strength values than in those obtained with the spray-dried powders, despite the lower density of the latter pieces. This was due to the greater ease of crack propagation through the pores in the pieces formed with the granulates obtained by the dry method.

In order to increase dry and fired mechanical strength, the milling, granulation, and pressing variables were modified. The increase in pressing moisture of the granules obtained by the dry method was found to provide the best results. By way of example, Table 1 details the results corresponding to the red-firing earthenware tile composition (AR). An increase in pressing moisture from 5.5 to 6.5% was sufficient to produce pieces with dry and fired mechanical strength that was the same as, or higher than, that obtained with the spray-dried powders of the three types of products.

Composition	Spray-dried powder AR	Granulate AR	Granulate AR	Granulate AR
Moisture content (%)	5.5	5.5	6.5	7.5
Pressure (kg/cm^2)	250	250	250	250
Dry bulk density (g/cm^3)	1.975	2.100	2.152	2.183
Dry mechanical strength (kg/cm^2)	31 ± 1	29 ± 1	39 ± 1	45 ± 1
Bulk density at 1110ºC (g/cm^3)	1.854	2.001	2.034	2.062
Mechanical strength at 1110ºC (kg/cm^2)	260 ± 10	230 ± 10	260 ± 10	280 ± 10

Table 1. Properties of the red-firing earthenware tile compositions.

Finally, granulates were prepared on an industrial scale of the different studied compositions, from which tiles were fabricated in an industrial plant. The following conclusions can be drawn from these trials:

- The granulates tested in the industrial trials performed satisfactorily during pressing, drying, glazing, and firing. No breakages or manufacturing defects were observed.

- The values for water absorption and fired density of the industrial tiles obtained were conditioned by the bulk density of the pressed compacts. The firing shrinkage of the red-body and the white-body earthenware tile was similar to that of the pieces obtained from the spray-dried powder. In the case of the red-body stoneware tile, the shrinkage values were lower.

- The industrial tiles obtained with the granulates exhibited better dimensional characteristics (calibre, wedging, and planarity) than those of the pieces obtained with the spray-dried powders. This was because of the greater dry bulk density and because the shrinkage–temperature slope did not increase for any of the granulates.

The quantification of the water and energy consumptions, as well as of the CO_2 emissions relating to the dry milling and granulation stages with respect to the current wet-milling and spray-drying process, established that the dry process:

- Consumed 80% less water.

- Consumed 80% less thermal energy but between 12 and 18% more electric energy, consequently reducing total energy consumption by 65%.

- Produced 80% fewer CO_2 emissions.

4. CONCLUSIONS

The study conducted opens the way for the preparation of ceramic body compositions by an alternative system, which is more respectful with the environment and more cost-effective than the current system.

In particular, the advantages of the new technology (dry milling in a pendulum mill followed by granulation) with respect to the current system of wet milling and subsequent spray drying are as follows:

- Lower water consumption.

- Lower thermal consumption.

- Abatement of gas emissions (CO_2).

5. ACKNOWLEDGEMENTS

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