STRATEGIES FOR A LOW-CARBON CERAMIC INDUSTRY. DRY GRANULATION

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1. INTRODUCTION

The reduction in energy consumption in the industrial ceramic sector and the ensuing reduction in greenhouse gas (GHG) emissions is one of the strategic objectives of the CerOh! Strategies project being conducted by ITC. This study describes one of the lines of experimentation, in which it is proposed to replace the wet preparation process of the material for the ceramic body with a much more eco-sustainable dry preparation method.

This report sets out the feasibility study of the dry process for industrial application, involving a comparative analysis of the different granulation systems available in the marketplace. To this end, the properties of the different products obtained were characterised for the comparative analysis, including an energy efficiency and economic analysis of each proposed process.

2. EXPERIMENTAL

2.1. SELECTION OF EQUIPMENT

The following three technologies were selected, Figure 1, for the comparative study:

- High-shear vertical granulator
- Low-shear horizontal granulator
- Roller–compactor technology: This consists of a compactor or briquettor which makes pellets from the moistened dry milled material, followed by a comminution system, Figure 1, which provides the granules with a certain spherical form. Finally, there is a sieving step to remove both the coarse and the fine fraction, these fractions being recirculated to the process start.

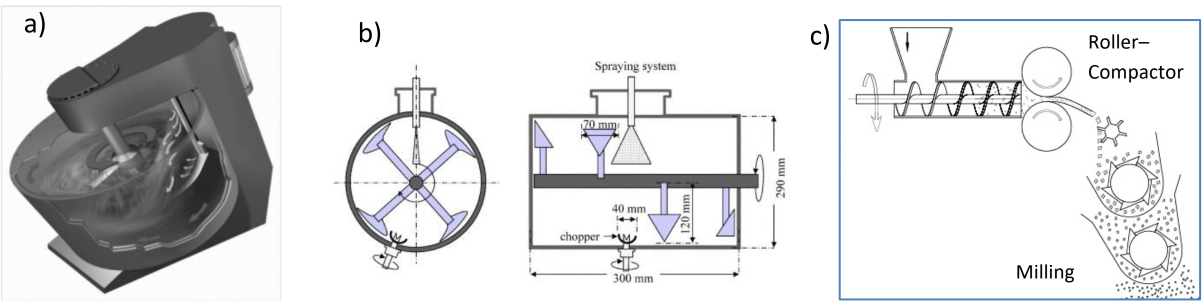

Figure 1. *Images of the different technologies used for granulating materials: a) high-shear vertical granulator: b) low-shear horizontal granulator: and c) roller-compactor*

Together with the comparative study of granule formation with different agglomeration techniques, the productivity of the methods was analysed, examining continuous and batch production.

2.2. GRANULATION TRIALS

The following variables were studied in each granulation process: amount of binder (water), granulation rate, granulation time, binder addition method, briquette forming intensity, and blade rotor speed in the roller–compactor. After establishing the optimum variables needed to obtain a granule size distribution that would facilitate the ceramic pressing process, granule properties were characterised, determining granule flowability, size distribution, sphericity, yield pressure, and Hausner ratio.

All the results from the granulation tests were compared with those of a granulate sample obtained by the traditional wet milling and spray-drying technique, as this is the technique that it is sought to replace. The moistened dry milled material for pressing was also characterised, without it undergoing an agglomeration process, to determine the savings resulting from this dry process and to quantify the improvement in material end properties on applying an agglomeration process. Energy consumption was also studied to determine the feasibility of implementing the granulation process in the ceramic tile production chain on an industrial level.

3. RESULTS

The results of the granule size distribution obtained for each of the different techniques used in particle agglomeration (Table 1) indicate that, with the dry granulation technique, the moistened particles hardly agglomerated, so that all the material was fine and hardly any agglomerates were obtained in the desired fraction (300–500 µm). Only the high-shear vertical granulator produced a similar size distribution to that of the spray-dried material, though the distribution curve shifted towards larger agglomerate sizes, instead of being centred in the target fraction (300–500 µm). Applying any of the studied techniques in the industrial process would require re-milling the (previously sieved) coarse material and introducing the fine material anew in the granulation process to obtain the appropriate size for pressing. However, this would clearly increase process electricity consumption and lower productivity, as a sieving separation operation would be needed that, at the high moisture contents displayed by the granules, would slow the process down.

Granule size distribution (%)	STD spray-dried powder Wet method	Powder Dry method	High-shear vertical granulator	Low-shear horizontal granulator	Roller–compactor (25Hz, 2H)
Fraction < 125 μm	4–5	58.8	3.7	1.2	9.9
Fraction 125–200 μm	10–12	13.7	8.4	2.4	5.1
Fraction 200–300 μm	20–21	7.5	19.1	6.8	3.
Fraction 300–500 μm	50–53	11.9	36.0	22.3	7.7
Fraction 500–710 μm	9–10	4.4	19.9	26.6	14.0
Fraction > 710 μm	3–4	3.7	12.8	40.8	59.4
Fine fraction increase (%)	-	53	-	-	5
Coarse fraction increase (%)	-	-	9	37	55

Table 1. *Comparative study of the granule size distributions and residues obtained with each granulation technique*

Comparison of the water consumption required to obtain the granulate with the different techniques (Table 2) reveals that the spray-drying process consumed 20% more water than the dry milling and granulation processes. Energy consumption was also higher in spray drying, owing to thermal energy consumption for evaporating the milling water, though this consumption has been minimised thanks to the electricity cogeneration process used in these types of facilities. In regard to the properties of the resulting granules, having the lowest Hausner ratio meant displaying the best flowability: thus, the powder obtained by the dry method exhibited too high a value, evidencing its cohesive character, followed by the granulate from the roller–compactor. This behaviour was also observed in the flow rate values.

Granulator	STD spray-dried powder Wet method	Powder Dry method	High-shear vertical granulator	Low-shear horizontal granulator	Roller–compactor (25Hz, 2H)
Starting water (%)	30	7	13	13	11
Granulate water content	6	7	11	12	10
Hausner ratio	1.21	1.55	1.25	1.31	1.33*
Mass flow rate (g/s)	36	Non-flowing	35	34	21,8*

**obtained after sieving the material at 1 mm*

Table 2. *Comparative study of the properties of the granules obtained with each granulation technique*

The morphology of the granules obtained with each technique (non-sieved samples) may be observed in Figure 2. These images reveal a large presence of fine (<125 µm) and coarse (>750 µm) material, compared with the STD a) spray-dried powder.

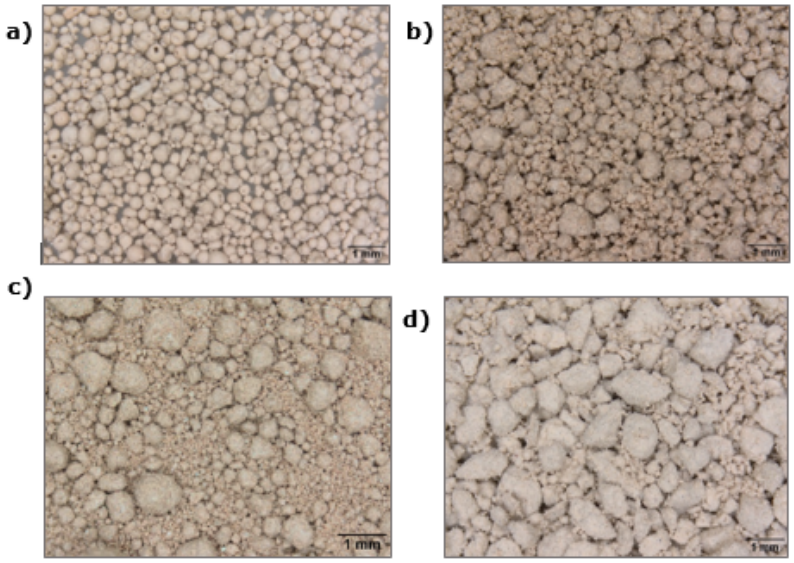

***Figure 2**. Image taken in a stereo microscope of the granules obtained by the different techniques compared in the study: a) spray-dried powder; b) material obtained in a high-shear vertical granulator; c) material obtained in a low-shear horizontal granulator; and d) material obtained with the roller–compactor technology*

4. CONCLUSIONS

The comparative study conducted allows the following conclusions to be drawn:

- The granulation process needs a 10–13% amount of water to achieve particle agglomeration, so that a drying process is required to adjust granule moisture content to the necessary pressing moisture content (6–7%). This would reduce the expected energy savings on having to include a drying step. Nevertheless, energy and water savings remain significant (50–70%).
- The three granulation techniques produced a bimodal granule size distribution, which was not centred in the 300–500 µm fraction. This could give rise to problems (owing to the amount of fine and coarse granules) unless sieving is performed followed by recycling of the resulting residues.
- The comparative study indicates that the technology yielding the most similar granule size distribution and flowability to that of the current product was the high-shear granulation technique. In addition, this technology exhibited the lowest residues of the fine and coarse fractions to be recycled in the process.

5. REFERENCES

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6. ACKNOWLEDGEMENTS

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