DEVELOPMENT AND VALIDATION OF A POPULATION MODEL FOR SIMULATING THE SPRAY-DRYING PROCESS OF CERAMIC SUSPENSIONS

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1. INTRODUCTION

The spray-drying operation of ceramic suspensions plays a key role in the ceramic industry. Its main goal is to transform an aqueous suspension of raw materials into a powder made up of spherical granules with a specific size distribution. These characteristics provide the spray-dried powder with an exceptional flowability, which makes it ideal for uniform filling of the press dies.

In the field of research into spray-drying equipment, approaches in modelling and simulation have traditionally focused on the use of computational fluid dynamics (CFD) [1]. Such models are usually complex and require significant computational resources. However, it has been verified that an alternative technique, known as the population balance model (PBM) [2], is able to replicate the results of CFD models in much shorter running times.

This poster presents a mathematical model, based on the PBM technique, which simulates spray drying in the ceramic tile production process.

2. EXPERIMENTATION

The experimentation focused on modifying the main input parameters in an industrial spray dryer, in order to analyse how the changes affected granule size distribution (GSD) and other output parameters, such as hot gas temperature and spray-dried powder moisture content, detailed in Table 1. Fig 1 shows the changes in starting conditions for each of the nine test operations (O1 to O9 in Table 1).

The first three operations consisted of modifying gas input temperature. Operations four, five, and six modified the opening of the main hot gas inlet valve. In the last three operations, under-pressure in the spray dryer chamber was varied by modifying end fan rotation speed.

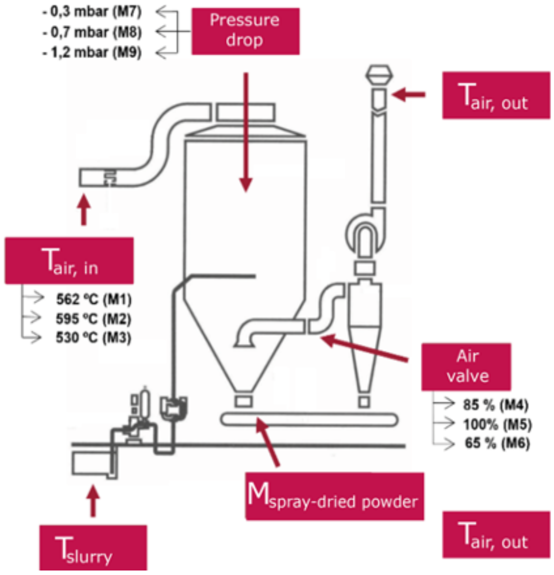

Figure 1: *Scheme reflecting the nine operations performed in the spray dryer.*

3. RESULTS

In order to use the proposed model, it is necessary to know the volume flow rate of the hot gases travelling through the spray dryer and the physical properties (density and solids content) of the processed suspension. These data, collected in the experimental measurements carried out during the test operations, and the determination of drop size distribution and drying gas temperature, enable calculation of resulting granule size distribution, spray dryer output gas temperature, and spray-dried powder moisture content.

	T_Output (°C)		Powder Moisture Content (%)		GSD			
					d_{50} (µm)		σ	
	Exp	Sim	Exp	Sim	Exp	Sim	Exp	Sim
O1	101.4	104.9	7.2	7.2	380.2	391.7	1.5	1.6
O2	106.7	108.8	5.5	5.5	365.8	387.1	1.5	1.5
O3	100.4	99.0	8.7	8.8	402.3	398.9	1.6	1.6
O4	102.0	102.1	7.2	7.2	399.2	394.1	1.5	1.6
O5	97.4	98.8	9.1	9.0	407.0	399.6	1.6	1.6
O6	108.4	111.0	4.5	4.5	378.9	384.8	1.5	1.5
O7	99.3	100.4	8.3	8.2	392.9	396.5	1.6	1.6
O8	95.2	95.1	9.0	8.8	404.9	398.1	1.6	1.6
O9	93.5	93.4	9.1	9.0	416.5	398.8	1.6	1.6

Table 1. *Comparison of the experimental and simulated results obtained in the nine operations performed in the spray dryer.*

Table 1 compares the experimental data and predictions of the model in the nine operations carried out. Generally speaking, the model exhibits appropriate accuracy, especially in estimating hot gas output temperature and, particularly, moisture content of the resulting spray-dried powder, with very low errors. Specifically, the estimation of output gas temperature exhibits a mean absolute error of 1.4°C, while that of spray-dried powder moisture content is 0.04%, in relation to the experimental values.

In relation to parameter d_{50}, which represents the granule diameter at which 50% by mass of the powder granules are smaller in size, more pronounced discrepancies are observed, particularly in the operating conditions under which resulting granule size shifted, relative to the nominal intermediate situation, towards both larger and smaller sizes.

By way of example, Fig 2 shows the cumulative powder granule size distribution for cases two and nine, which are the scenarios with the greatest discrepancies in d_{50}. It shows, as noted above, that granule size in operation 2 is slightly overestimated by the model, while granule size in operation 9 is underestimated. However, the model's consistency in qualitatively predicting the lowest and highest d_{50} values in the same scenarios as those observed in the experimentation should be highlighted.

The GSD estimation by the model involves simultaneously determining the energy and mass balances of the spray dryer, together with the drop population balance. This is a complex procedure, owing to the interdependence of these equations and the need to consider multiple variables. However, the results obtained to date demonstrate that the model effectively addresses this complexity, quite accurately interpreting actual spray dryer performance.

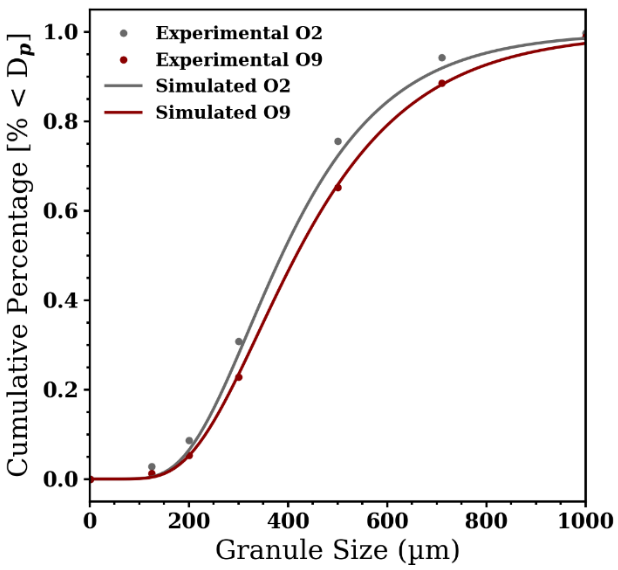

Figure 2: *Comparison of experimental and simulated granule size distributions in operations O2 and O9.*

In order to improve the accuracy in estimating the resulting powder granule size distribution, it is essential to perform further experimentation, initially not considered in this study. This additional research will allow correlations to be established between the properties of the processed ceramic suspensions, characteristics of the spray nozzles, and pumping conditions with the size distribution of the drops generated in the spray dryer's drying chamber and, in turn, with resulting granule size.

4. CONCLUSIONS

- The simulation model exhibits good accuracy in predicting critical variables such as hot gas temperature and spray-dried powder moisture content, with relative errors below 3%.
- Although the model is able to qualitatively predict the trends in d_{50}, it displays certain quantitative discrepancies, particularly in scenarios where d_{50} is particularly high or low.
- The results suggest that the model is robust and consistent under different operating conditions, although it could benefit from further fine-tuning to improve the accuracy in estimating d_{50}.

5. REFERENCES

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[2] Teixeira, R., & Oliveira, F. (2015). CFD simulation of spray drying process for ceramic slurry. Ceramics International, 41(12), 11159–11167.