
# Experimental and CFD study of multi-zone vortex chamber spray dryers

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***Highlights***

- High-G intensified interfacial transfer of mass, heat and momentum
- Axial and radial multi-zone concepts studied, radial concept most promising
- Short-contact efficient initial drying with hot air to prevent degradation
- Fast evacuation of initially dried particles to cold air zone for final drying

## 1. Introduction

High-G operation in vortex chambers allows intensifying interfacial mass, heat and momentum transfer [1]. In previous studies, application to particle drying [2,3] and fine particle coating [4] was demonstrated. Combining high-G intensified gas-solids contact, gas-solids separation and solids segregation was also considered [5]. In the present work, intensified spray drying is studied. The objective of the multi-zone design is to combine hot air injection for fast and efficient initial drying of the droplets with rapid evacuation of the initially dried particles to a cold-air zone to prevent degradation. Different designs were studied, both experimentally and by means of CFD.

## 2. Methods

The experimental set-up is flexible and allows varying the multi-zone concept, the number of vortex chambers/zones and their individual design, the type of spray nozzle and the solids outlet design. The maximum total air flow rate is 1000 $Nm^3/hr$, the maximum liquid flow rate 6 g/s. Hot air temperatures of up to 350°C can be used. Both hollow-cone and full-cone nozzles were tested.

Three types of experiments are carried out: (i) in the absence of liquid injection, (ii) injecting water, and (iii) injecting milk. Detailed measurements of the temperature profiles in the device were carried out using a total of 16 thermocouples. The data and comparison of the profiles with (i), (ii) and (iii) allow gaining understanding of the complex flow pattern of the gas and droplets and the extent of evaporation in specific regions. Deposition of powder on the walls was also carefully analyzed.

CFD simulations used a RANS-approach and a coarse-grained discrete particle model to track the motion of the droplets. Evaporation was accounted for and the behavior of droplets of different size studied.

**Figure 1.** Experimental pilot (exterior and interior views).

## 3. Results and discussion

Axial multi-zone operation is challenging. As a result of the strong centrifugal force, hot air injected in one zone is very rapidly axially mixed with cold air. As a result, the size of the hot zone is (too) limited and the cold zone cannot be kept at the desired low temperature when sufficient heat is to be supplied. The pressure drop over the vortex chamber is also relatively high.

A novel radial multi-zone concept [6] allows the generation of a sufficiently large and well-contained hot zone and rapid evacuation of initially dried particles to a well-contained low-temperature zone for final drying. Furthermore, the hot air is no longer injected through the vortex chamber(s), reducing the pressure drop over the device, especially on the hot air supply. Efficient production of high-quality powder with the radial multi-zone vortex spray dryer was demonstrated. The influence of the spray nozzle design was, however, found to be important.

## 4. Conclusions

Experimental studies and CFD simulations of spray drying in different multi-zone configurations show that axial motion in the vortex chamber is significant. This makes the use of an axial multi-zone concept challenging. A novel radial multi-zone vortex spray dryer shows promising performance in combining fast and efficient initial drying with hot air with high-G intensified evacuation of the initially dried particles to a cold air zone to prevent product degradation.

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Spray drying; Vortex chamber; High-G; Process intensification