Analysis of confined spray processes for powder production

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Abstract

Solid particles or powders may be produced in spray processes like spray drying or spray polymerization. The tailoring of the particle and powder properties that are produced within spray processes is influenced by various unsteady transport processes in the dispersed multiphase spray flow in a confined spray chamber. In this context differently scaled spray structures in a confined spray environment have been analyzed. The basic setup of the study consists of a twin-fluid atomizer central top-spraying in a confined spray chamber. The atomizer gas can be heated up to 500°C, providing enhanced disintegration and drying conditions. In contrast to a traditional spray drying process by using heated atomization gas in the twin-fluid atomizers no superimposed massflow of hot dry air is applied. Thus energy may be saved. Mixing phenomena of momentum, energy and species in the near region of the nozzle play an even bigger role for this hot-gas atomization and drying process than in a conventional spray dryer. Large scale spray structures in enclosures like:

- the oscillation of the spray plume,
- the shear flow instabilities at the spray edge,
- gas entrainment and recirculation zones and
- droplet cluster formation

greatly influence the heat and mass transfer for individual droplets within the spray cone. These spray structures are significantly influenced by the nozzle's operational parameters (air-liquid ratio, atomizer gas pressure, feed fluid, etc.). Another process parameter which has been scarcely investigated so far is the geometry of the spray chamber. Therefore differently shaped conical spray chamber designs with square cross sections have been analyzed experimentally and numerically.

Numerical simulations of the bounded spray flow have been carried out using Reynolds-Averaged-Navier-Stokes models (RANS) and Large-Eddy-Simulation (LES) models with lagrangian particle tracking for the droplet motion. The trajectory of droplets/particles in the gas has been tracked with respect to their environment to estimate the drying conditions. Especially the local droplet concentration and the turbulent motion characteristics of the gas phase and its interaction with the droplets have been analyzed. While the spray structures outside the spray cone flow like recirculation and entrainment zones of gas can be well predicted by RANS models, the prediction of large scale turbulent structures within the spray cone is realistic to be realized only with Detached-Eddy-Simulation (DES) and LES models that are more complex due to the modeling and computation of the initialization and propagation of vortex patterns. Synthetic perturbation generators for the inflow conditions have been applied to induce realistic vortex patterns and to promote the unsteadiness of the spray flow. In the focus of the LES investigations is the spatial distribution of droplets within the spray. The specific process shows significant clustering of droplets, which is induced by the coherent flow structures within the spray. The numerical results show good agreement with Particle-Image-Velocimetry (PIV) measurements in a lab scale process under isothermal conditions. The Influence of the spray chamber design on the droplet/particle-gas interactions will be analyzed. The project is part of the SPP 1423 Prozess-Spray: „Herstellen funktionaler Feststoffpartikeln in Sprühverfahren: Von den Anforderungen an das Pulver und an seine Eigenschaften zum geeigneten Prozess" funded by the German Research Foundation (DFG).

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