Analysis of time-dependent spray structures in spray processes in enclosures with square cross sections

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Abstract

In this contribution the influence of different spray chamber designs with square cross sections on unsteady spray flow structures is discussed. The effect of the spray chamber design is controversely analysed in the literature. The product properties from spray processes highly depend on the local averaged, but also the instantaneous mass and heat transfer processes within the spray. These mechnisms are affected by particle trajectory as well as by local droplet concentration. Both phenomena are investigated experimentally and numerically drawing special attention to gas-particle interactions.

Introduction

Unsteady phenomena of sprays greatly affect the product quality of the spray process. For example in solid particle production in spray processes, the powder quality (size, shape, ..) strictly depends on the local drop behaviour. In this paper the large-scale movement of the droplet jet and the ambient air as well as local clustering of droplets is analysed. In enclosed spray processes spray flapping accompanied by precession can occur. The strength and size of entrainment and recirculation zones in the spray influences the retention time of particles and are therefore to be analysed quantitatively. Additionally, the small-scale clustering of droplets within the spray cone is reviewed. The interactions of particles with large-scale eddy structures within the gas will be discussed.

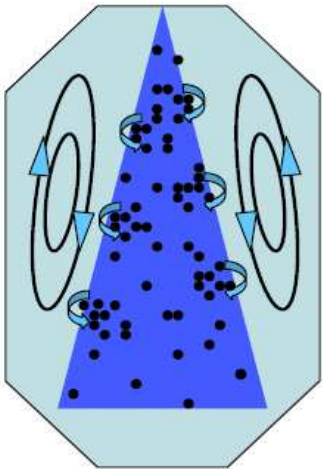

Figure 1. Recirculation and cluster formation in Sprays

Materials and Methods

External and internal mixing twin fluid atomizers under different feed und environment conditions are used. The downward directed spray is located at the top of a designed spray chamber. The Spray chamber design varies in the size and aspect ration of the cross section as well as in the opening angle.

Figure 2. Conical spray chamber

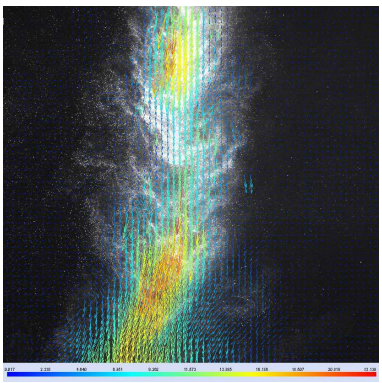

Figure 3. Particle image velocimetry-evaluation

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Unsteady particle cluster formation is determined quantitatively by evaluating the spatial inhomogenity within planar light sheets. 2D-PIV techniques are employed to determine the instantaneous velocity field within the spray. The local homogeneity of the spray structure is evaluated by means of statistical observations of planar drop locations and movements. A method proposed in [3] is used to specify the derivation and probability of inhomoneneities to occur. Additional large-eddy simulations using the Euler-Lagrangian approach have been conducted to predict the highly time-dependend spray structures. The large-scale motion of the spray is analysed through highspeed videography and pressure measurements. The environment factor which has great influence on the macroscopic movement of the spray is interpreted by the study of different spray chamber designs. Therefore different variants with square cross sections with streamwise expansion are reviewed.

Results and Discussion

Measurement results show that there is a certain difference between enclosed and open spray processes. Flapping, precession and recirculation of droplets is highly dependend on the spray chamber design. High ratios of gas-water flow rates lead to instabilities in the spray process that can be minimized by choosing a certain spray chamber geometry. On the other hand instabilities in sprays can be used to minimize the clustering of droplets. Optimization citeria can be found to predict certain flow structures. Inhomogeneities in the particle concentration likewise occur at the spray edge, resulting from interaction with turbulent eddies in the air. Tracking of single droplet clusters shows that there is a big difference in momentum, concentration, etc. between droplets within the cluster and those in between. Averaged flow fields yield only little information about the conditions of a particle in the investigated sprays. Simulations of spray processes close the gap between the experimental results suffering from low temporal resolutions and the highly time-dependend spray flow structures. Simulation results show high dependence on the initial conditions. Coupling of discrete phase and air is also discussed.

References

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