IFPRI Project Abstract

Characterization of Spray Drying Nozzles at Industrially Relevant Conditions

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Project Objective:

Spray drying is an industrial process used in the production of powdered products such as many pharmaceuticals. Pilot scale experiments are used to determine the optimal operating conditions of the sprays for complex fluids, and correlations are used to extrapolate to the production scale. Current correlations lack validation across a wide range of nozzle sizes and for highly viscous fluids which are relevant to the pharmaceutical industry. This study aims to develop these correlations and scaling relationships for a wide range of nozzle sizes and fluid viscosities by focusing on the near-nozzle breakup behaviour. Additionally, the formation and breakup of fluid ligaments will be quantified and analyzed.

Approach:

1. Develop benchmark data set for near-nozzle spray characteristics (Phase 1)
    a. Complex fluids: High viscosity, Polymeric
    b. Pilot and production nozzle sizes
2. Determine correlations for nozzle scaling and ligament formation and breakup (Phase 2)
3. Develop correlations for the effect of ambient temperature (Phase 3)

Recent Results:

For pressure swirl nozzles, multiple experiments with different operating conditions have been completed. Different fluids with different viscosities and at high injection pressures (500 to 900 psi), using nozzles with a wide range of orifice diameters (0.02” to 0.129”) are tested. An imaging technique is used for spray characterization. A larger number of images are collected at several axial and radial locations in each spray. The measurements not only provide the global SMD and distributions, but also the local SMD to study the spray patterns for different operating conditions. The particle size distributions have a unimodal distribution for some operating conditions, while show bimodal distribution for other operating conditions. Near nozzle images taken for the sprays show that at high pressures, fluids accumulates on the wave crests and troughs of the surface waves, which will generate thick, spanwise ligaments. The thin liquid sheet in between the wave crests and troughs perforates forming thin streamwise ligaments. These ligaments then generate small droplets further downstream. A new atomization model is proposed based on the sheet perforation mechanism, which well predicts the spray droplet sizes. The spray size distribution is also predicted using a summation of two gamma distributions.

In two-fluid atomization, the simultaneous existence of multiple breakup modes were identified; one in which surface waves on the liquid jet break, and one in which the bulk of the liquid core breaks. The presence of these two modes of breakup result in multi-modal particle size distributions (PSD). We have related each breakup size and the relative frequency between them to the PSD, and have developed models for the characteristic size of each breakup mechanism. The underlying mechanism of interest for high viscosity fluids is the membrane or bag-type breakup. We have performed experiments on the breakup of single suspended droplets, to determine the characteristic sizes that are generated, and to quantify the breakup process. The breakup process consists of three stages: deformation, formation of the initiation structure, and growth to breakup. We have developed a model for the first two stages, with the third in progress. Initial findings using empiricisms for the final stage show good agreement with our experimental results for the breakup sizes.

Next Steps:

For pressure swirl nozzles, more experiments with polymeric solutions such as HPMCAS/acetone solutions and maltodextrin/water solutions will be performed. Image analysis algorithm for characterizing the ligaments will be completed and used to find the thickness of the ligaments. This information will be used to determine the mass accumulated in the wave crests and troughs to complete the correlation for the proposed model for the atomization by pressure swirl nozzle.

For two-fluid atomization, the single droplet breakup experiments will be extended to high viscosity fluids to complete the breakup model. Experiments will provide the required information on the surface and core breakup modes and the relative frequency between them to describe the PSDs of sprays. The spray database will be further developed with production scale nozzles as well as higher wt.% glycerin mixes and HPCMS mixtures.