IFPRI Project Abstract

Spray characterization at industrially relevant conditions

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Project Objective:

Spray drying is a process used in the production of powdered products such as pharmaceuticals. Pilot scale experiments are used to determine the optimal operating conditions of the sprays and correlations are used to extrapolate to the production scale. Current correlations lack validation across a wide range of nozzle sizes and for fluids relevant to the pharmaceutical industry. This study aims to develop these correlations for a wide range of nozzle sizes and fluid viscosities by focusing on understanding and mechanistically modelling the near-nozzle breakup behaviour.

Approach:

1. Develop benchmark data set for near-nozzle spray characteristics for lab and production nozzle scales with high viscosity and polymeric fluids (Phase 1)
2. Determine correlations and models for nozzle scaling and for ligament formation and breakup (Phase 2)

Recent Results:

Phase 1: A benchmark database of droplet size distributions and near nozzle images has been generated for pressure-swirl and two fluid nozzles of varying scales for water (low-viscosity), glycerin (high-viscosity), and CMC (polymeric) solutions. The database is presently being packaged for online distribution.

Phase 2: Modelling of the spray behaviour was focused on two nozzle designs:
Pressure-swirl: A perforation-based atomization model was proposed for atomization in pressure-swirl nozzle based on images at near nozzle region. The model predicted two kinds of ligament with different characteristic diameter. Droplet distributions downstream showed bimodal distributions, with each mode related to one type of ligament. A semi-empirical correlation was developed by fitting a mixture of log-normal distribution to the bimodal volume distribution. The major mode corresponding to large span-wise ligament takes up 95% of total volume and outweighs the minor mode and the parameters in the distribution were correlated with physical parameters. A series of experiments on fan spray nozzles had been done to further study the relationship between operating conditions and ligament sizes. Mass ratio between two types of ligaments, ligament sizes at the breakup positions were measured using image processing techniques. Ongoing work aims to understand the physics between these parameters and operating conditions.

Twin-fluid: The dynamics of air-assisted atomization were studied in the form of droplet breakup, resulting in a model that describes how the initial deformation is related to the mean size of the resulting ligaments (link), while a variety of mechanisms leads to the distribution of droplet sizes (link). The droplet breakup model was applied in the context of a twin-fluid nozzle, providing a good prediction of the droplet size distribution for a wide range of operating conditions and nozzle scales. High viscosity slows the deformation, leading to larger sizes overall, and slows the breakup, leading to long-lived ligaments. For polymeric fluids with high extensional viscosity, only the breakup is slowed, leading to a network of thin, stringy ligaments. Ongoing work aims to include such effects in the model.

Next Steps:

We have proposed to extend this project by further studying the atomization of complex fluids, such as solid suspensions and fluids with significant elongational viscosity, to further develop models and correlations for the droplet size distribution from such fluids.