IFPRI Project Abstract

Spray characterization at industrially relevant conditions

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Project Objective:

The present work is a continuation of our research on the atomization of high viscosity and polymeric fluids. Previously, we developed models to predict droplet size distribution based on breakup morphologies occurring in twin-fluid and pressure swirl nozzles. Near nozzle images indicated that the ligaments of highly viscous and polymeric fluids experience stretching and become thinner before they break up into droplets. In addition, solid particles in slurries cause a different type of ligament breakup as compared to pure fluids. The main objectives of this continuation project are to model the ligament breakup of highly viscous and polymeric fluids and slurries, and use those models to develop models to predict droplet size distribution in sprays of such fluids.

Approach:

1. Design experiments to simulate ligament breakup subject to various gas flows.
2. Model ligament breakup of highly viscous and polymeric fluids and slurries under high relative velocity air flows.
3. Modify existence models by implementing ligament breakup models obtained in (2) to predict droplet size distribution for such fluids.

Recent Results:

We have designed a liquid bridge experiment, in which a liquid ligament can be pulled rapidly to form ligaments with various diameters and lengths. The ligament is then subjected to an air cross flow. Glycerin/water solutions, CMC/water solutions and Neodol slurries with different initial diameters are exposed to different air velocities. The shear viscosity determines the extent of ligament stretching pulled without air, while elongational viscosity governs the ligament breakup in air cross flows. Large diameter ligaments flatten by the air cross flow and may result in bag breakup. Whereas, small diameter viscous ligaments go only through stretching and ligament thinning, followed by ligament breakup into droplets. The results show that the critical Weber number ($We = \rho_g U_g^2 d_{lig,0}/\sigma$) for the bag formation is $We_c = 11$. For $We < We_c$, ligament experience stretching and thinning, and then form beads-on-string structure. For $We > We_c$, ligament experience bag breakup resulting into small membranes. The membranes break up into small droplets and rims experience stretching and form beads-on-string structure. We have also implemented a ligament dynamic model to determine the bead formation in flapping ligaments. This model describes how the shape of the ligament's central axis and the shape of cross sections on ligament changes given its initial orientations. The model gives information on initial formation of beads-on-string structure in the ligament breakup.

Next Steps:

We are going to continue developing the model on ligament stretching to predict the sizes of beads and length of strings between the beads. We will also build a model for the bag breakup scenario to give characteristic sizes of droplets generated from both membranes and rims. This will give a complete model to predict droplet size distribution from ligament breakup in air crossflow for highly viscous and polymeric fluids.