Ligament and Droplet Characteristics in Prefilming Airblast Atomization

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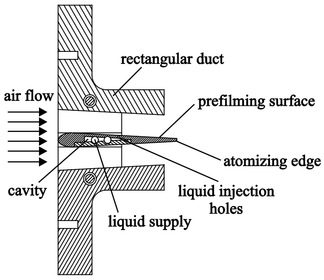
Abstract

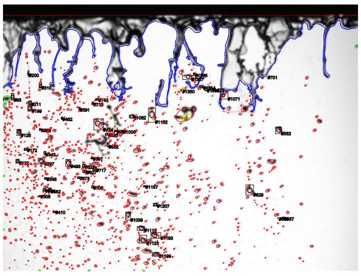
Liquid film breakup of three different geometrical variants of a planar prefilming airblast atomizer have been studied using advanced Particle Tracking Velocimetry (PTV) coupled with ligament tracking. In addition to the variation in geometry, liquids with different physical properties (surface tension, viscosity) have been tested. The liquid mass flow rate and mean air velocities were varied over a wide range of test conditions. A post-processing algorithm was developed to capture the ligament and droplet sizes and their velocities. For the test conditions investigated, it was observed that the mean air velocity and the thickness of the atomizing edge are the key parameters that influence the breakup process. From the database of test cases, correlations for the ligament breakup frequency, Sauter mean diameter and mean velocity of the primary droplets are derived.

Many previous investigations into prefilming atomizers consist of spray measurements at elevated pressures and temperatures using either actual nozzles [1] or simplified planar injectors [2]. Due to limited optical access and difficulties performing measurements in the dense spray regime, most of experimental data consists of downstream drop size measurements and are of limited value for validation of predictions of the primary breakup. To remedy this, the present work focuses on measurements on the ligament formation out of the liquid film and the primary breakup process of these ligaments into initial droplets.

Because sufficient optical access is of primary importance, a two-dimensional abstraction of an airblast atomizer was used for all experiments (Fig. 1a). All measurements were performed at ambient conditions. The mean air velocity could be adjusted between $\bar{u}_g$ = 20 to 70 m/s. The prefilming length, i.e. the distance between the injection holes and the atomizer edge is varied between 20.6 and 47.6 mm and the atomizer edge height is either 1 or 2.5 mm. The film load could be adjusted between $\dot{V}/b$ = 25 to 75 mm²/s, where b = 50 mm represents the width of the wetted surface. Six test liquids were used for the experiments in order to cover a wide range of densities, viscosities and surface tensions.



(a) Prefilmer: length is 20.6mm, atomizing edge thickness is 1mm



(b) Instant shot of ligament formation and break up
$\bar{u}_g$ = 60 m/s, $\dot{V}/b$ = 25 mm²/s, σ = 0.0255 kg/s², ν_l = 1.09x10-6 m²/s

Figure 1: experimental atomizer (a) and evaluated PTV image (b)

In order to investigate the formation of the ligaments and the breakup into single droplets, a commercially available PTV system was used for the image acquisition. For the post-processing of the data a Matlab® routine, developed by the Institut für Thermische Strömungsmaschinen (ITS) [3], was used (Fig. 1b).

Initial results indicate that the governing parameters of the breakup process are the mean air velocity and the thickness of the atomizing edge. It is found that the ligament shape and size and the Sauter mean diameter (SMD) are almost not affected by the prefilming surface length within the range investigated in these experiments. The variation in liquid properties and liquid loading also appears to have a minor effect on the primary breakup itself. The differences in characteristic ligament properties, SMD and droplet velocities of the different test cases studied are compared and the effects of flow conditions, liquid properties and geometry of the atomizers are elucidated. Correlations are derived for the breakup frequency, SMD and mean droplet velocity.

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