Chapter 6

Disintegration of Liquid Sheet Produced by Swirl Injector

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ABSTRACT

The development of liquid sheets that emerge from nozzles is influenced mainly by their initial speed and by the physical properties of the liquid and the ambient gas. A minimum speed of the sheet is necessary for its enlargement against the superficial tension that tends to contract the surface. As this speed increases, the sheet expands until a main extremity is formed, where balance exists among the superficial tension and the inertial forces. The form and regularity of the sheet’s disintegration process has influence in the size distribution of the produced drop and in the Sauter mean diameter (SMD). The initial thickness of the produced liquid sheet is important to determine the medium size of obtained drops. It was observed that thicker films produce thicker ligaments and larger drops. The medium drop diameter produced in conical sheets of pressurized swirl atomizers is calculated according to the thickness of the sheets and in the wavelength for the maximum growth tax.

INTRODUCTION

The development of a liquid sheet that emerges from a nozzle is influenced mainly by its initial speed and for the physical properties of the liquid and of the ambient gas. It is necessary a minimum speed of the sheet for its enlargement against the force of superficial tension, which tends to contract the surface. As larger this speed is, more the sheet expands and it is prolonged until that a main extremity is formed, where balance exists between the superficial tension and the inertial forces. Its disintegration may happen with or without perforations in the liquid sheet.

The generation of a wave movement in the sheet, through the one which areas corresponding to one or half wavelength of the complete oscillation, will be torn apart before the extremity is reached. These torn areas, when don’t suffer disintegration for the action of the air or turbulence, they contract quickly under the action of the superficial tension forming a net of lines.
Fraser (Fraser, Dombrowski, & Routley, 1963) showed that the regularity of the disintegration process and the uniformity of production of lines has a big influence in the distribution of the size of the drop. Perforations that happen in the sheet at the same distance of the nozzle have a similar formation and the size of the drop is constant in the disintegration of perforated sheet. The disintegration of the wavy sheet is highly irregular, and consequently the drop sizes are much more varied.

Atomizers that unload the liquid in the form of a sheet are usually capable to exhibit all the three manners of sheet disintegration. Sometimes, two different manners happen simultaneously, and its relative importance can influence a lot, so much in the drop size, as in the size distribution.

Dombrowski and Fraser (Fraser, Dombrowski, & Routley, 1963) used an improved photographic technique and a source especially projected to combine a discharge and intense illumination with short duration, and established that the ligaments are caused, mainly, for perforations in the liquid sheet. If the perforations are caused by attrition with the air, the ligaments separate very quickly. However, if the same ones are created through other means, as turbulence in the nozzle, the ligaments break up more slowly. They concluded that (1) liquid sheets with high superficial tension and viscosity are more resistant to breaking and (2) the effect of the density of the liquid in the disintegration of the sheet is very small.

Dombrowski and Johns (Dombrowski & Johns, 1963) observed that the interaction between liquid and air produces unstable waves, which dissolve in fragments that contract in ligaments and these ligaments break up to generate minor drops due to the air velocity, because the ligaments are finer and are formed closer to the nozzle.

The initial thickness of the liquid sheet is directly proportional to the size of the nozzle, and is important to determine the medium size of the produced drop, as it was observed that thicker films produce thicker ligaments and larger drops.

The comparison among the magnitude of the disturbances wavelength that cause rupture of the liquid sheet with its thickness is used by Dumouchel (Dumouchel, Ledoux, Bloor, Dombrowski, & Ingham, 1990) to classify the liquid sheets in two groups. In the first case, when the magnitude of the wavelength of the disturbances in the liquid surface is in the same order of the sheet’s thickness, the rupture process begins close to the exit of the nozzle and extends along the length of the sheet, and the ligaments, great structures and drops are unstable and break up in smaller drops.

In the second case, when the magnitude of the wavelength of the disturbances in the surface of the liquid is smaller than the thickness of the sheet, disturbances in the surface of the liquid are confined to a small area close to the surface and, as the disturbances grow, fine ligaments and small drops are removed from the surface. This disintegration process happens in areas far from the limits of the nozzle.

**Plane Sheets**

The mechanism for the disintegration of plane liquid sheets moving in the air was studied theoretical and experimentally by York et al. (York, Stubbs, & Tek, 1953). They concluded that the instability and wave formation in the interface among the continuous and discontinuous phases are the main factors in the rupture of a liquid sheet in drops. Forces of surface tension try to do the protuberances return for its original position, but the local static pressure of the air decreases (corresponding to the local increase in speed) and that tends to enlarge as becomes more distant to the external protuberance. This corresponds to the pattern of instability for induced wind, where the forces of surface tension are opposed to any movement of the interface of its initial plan and try to reestablish the balance, while a forced aerodynamics increases any divergence of the interface and promote, like this, the instability.