Drop Size and Drop Size Distribution Measurements by Image Analysis

J. B. Blaisot
CORIA UMR 6614, University of Rouen, France
blaisot@coria.fr

Abstract

One important issue in drop sizing by image analysis is the determination of the contour of the drops. As image is a signal particularly well adapted to human perception, it is often considered that raw data from an image can deliver quantitative information on the object imaged without needing any underlying physical model. This is not sufficient for precise determination of drop contours in the image of a spray as the grey level corresponding to the contour strongly depends on the degree of focusing of a drop. It is shown in the present paper how an imaging model can help in determining this contour and thus in measuring the drop size. Recent advances made on an imaging model developed for application to spray sizing and drop size distribution measurements is presented. The imaging system is modeled by its point spread function (PSF) which can be considered as the response of the system to an infinitely small object source. Digital image capturing systems are classified in two categories, depending on the PSF width compared to the pixel width. Optical systems under consideration belong to the optics limited (OL) category for which the PSF is covered by several pixels. This is an important feature the imaging system must fulfill to apply criteria derived from the model. Also, even though objects under consideration are transparent liquid drops, it is shown that refraction can be neglected since those criteria are based on measurement made at the outline of the drop images.

The optical settings of the imaging configuration must be carefully adjusted. Using a backlight configuration and a collimated light source is suggested to obtain high contrast images and a large DOF. An imaging model is used to derive useful relation for drop sizing application. The principle of the model, modeled image profiles and image parameters relevant for drop sizing are introduced. It is shown that image profile is controlled by two parameters that depend on the object properties (size, position, opacity) as well as on the imaging system properties (PSF). Image contrast, image width and grey level gradient at image edge are then used to characterize image profiles properties and to derive relation between object and image properties.

A sizing criterion and a focus selection criterion are derived from these relations. The sizing criterion allows determining the grey level to be used for locating the image contour and measuring the drop size. This is the main advantage of the model. Indeed, no calibration or correction is done on measurements made on the image to obtain the drop size. This criterion is based on the adjustment of the reference grey level, depending on the value of the image contrast. The focus selection criterion is based on the measurement of the PSF half-width and implies that an OL system must be used. It uses a relation between the grey level gradient and the image contrast. The derived criterion does not depend on the size of the drop. It is thus used to select droplets in a spray according to their focus position, independently from their size.

An application to spray measurement is presented. It is shown that the sizing criterion allows measuring drop size over a large DOF. The sizing error remains of the order of the pixel size over the range of measured diameter [10µm – 1500µm] when focus selection criterion is used. The selection criterion, coupled to the calibration of the PSF of the system, determines an effective depth of the measurement volume about 0.6 mm. It is shown that increasing this depth must go with an increase of the minimum diameter of the sizing range. If not, underestimation of the drop size distribution may occur for the smallest droplets. Sizing error due to an underestimation of the reference grey level is also evaluated and found to be less than 7% for acceptable contrast error. Image segmentation and sub-pixel contour extraction techniques are briefly presented at the end of the paper. These techniques are used to enhance the sizing procedure. Indeed, the complex image segmentation technique, using continuous wavelet transform computation, allows detecting of almost all the drops that are visible to the naked eye in an image. Real-coordinate contour obtained from sub-pixel contour extraction is analyzed as a curve in a continuous space described by a limited set of points. Size and shape parameters determined from this contour do not present discrete values, even for the smallest droplets. This leads to an effective enhancement of the sizing and of the shape analysis procedures. Partial overlapped droplet images are detected from the analysis of sub-pixel contour analysis.