Representation of Laser Diffraction Diameter Distribution with a 3-Parameter Generalized Gamma Function

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Abstract

The ability of a mathematical function to represent liquid spray drop-size distributions is usually quantified by exploring its capability of representing experimental data. Experimental diagnostics are not sensible to the same spray characteristics. We therefore have reasons to believe that the more appropriate mathematical function to represent experimental data depends on the diagnostic. Thus, the question of the appropriate mathematical distribution to represent measured data should be addressed for a given diagnostic. This work adopts this strategy and concentrates on the relevance of representing Laser Diffraction Technique (LDT) volume-based drop-diameter distributions with 3-parameter Generalized-Gamma functions.

The first part of the paper addresses the question of the number of adjustable parameters. The 3-parameter Generalized-Gamma function is mathematically identical to the Nukiyama-Tanasawa distribution whose ability to reproduce liquid spray drop-size distribution has been reported by many previous investigation and has not to be proved. However this distribution might suffer from parameter instability that manifests when different parameter triplets provide almost identical volume-based drop-diameter distributions. This suggests that two parameters might be enough when fitting the general shape of this distribution. However, it is demonstrated here that these distributions have a very different characteristic feature in the small drop population. Being analogous to a fractal dimension, this characteristic feature is related to the physics of fragmentation in the literature, and is believed to be of paramount importance. Therefore, the three parameters allow having independency between the distribution shape and its fractal characteristic. Furthermore, it is demonstrated that the three parameters are required to reproduce mean-diameter series as those reported by previous LDT measurements.

These results demonstrate that three parameters allow reproducing LDT drop-size distributions and going above the simple exercise of curve fitting. A protocol to determine these parameters is proposed. One of the parameters is determined from the actual spray small-drop population. However, the small-drop population reported by the LDT distribution might be affected by the presence of non-spherical droplets. Thus, the information related to the actual spray small-drop population is obtained with another diagnostic.

The second part is an experimental investigation in which water sprays are analyzed by two different diagnostics, i.e., LDT and Image Analyzing Technique (IAT). These diagnostics perform a different spray sampling. LDT performs a line-of-sight spray sampling in the direction of the incident light propagation whereas the spatial integration of IAT in this direction is limited to the depth of field of the image which is less than the spray thickness and dependent on the size of the drops. To overcome this problem, IAT is improved in order to perform tomographic spray sampling. The information reported by each spray slice is cumulated and allows characterizing the whole spray as does the LDT. This tomographic exploration reports interesting information on the spray structures. Some examples are presented in this paper.

The surface-based diameter distributions reported by the two diagnostics are not identical and in particular, in the small diameter range. This disagreement is believed to be due to the contribution of non-spherical drops. The small drop population reported by IAT is constituted of small and spherical elements. It is seen as the actual spray small-drop population and used to determine one parameter. The two other parameters are determined by fitting the LDT distribution. The results show excellent fits and no instability of the mathematical parameters is reported: they show a clear relationship with the injection pressure that was the experimental parameter of the present work. Furthermore, besides the shape of the distribution, good reproductions of the fractal characteristic and of the mean-diameter series are obtained. Finally, one of the adjustable parameter reported a clear correlation with the average lack of sphericity of the droplets that was measured from the images. This demonstrates that the LDT distributions are well influenced by the droplet shapes and include average information on this very point.

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