Geometric effects in the design of multijet atomizers

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Abstract

The multijet atomization strategy stands out as competitive in the production of liquid atomizers with relatively simple geometries, producing sprays from the impingement of two or more jets ($N_j \geq 2$), with a relatively low injection pressure and, consequently, low flow rates ($< 1.5l/min$). However, there are two geometric factors affecting the design of these atomizers and, eventually, the atomization process itself, which are scarcely approached in the literature: i) the pre-impingement distance (l_{pi}) of the jets; ii) and the jets' misalignment. This paper analyzes the influence of these parameters on the structure of the liquid sheet formed after the impact of two jets, as well as on drop size. An experimental setup has been built with the possibility of studying multijet sprays up to $N_j = 4$, where each jet has 4 degrees of freedom (x, y, z, θ, the later corresponds to half the impingement angle) and the flow rate is controlled individually. The range of jet Reynolds (Re_j) numbers lie between 1485 and 5729 and the impingement angles from 90° to 120°. The pre-impingement distances vary from 2.5 to 7.5 of the jet diameter (d_j) and the misalignment from 0 to 50% of d_j. The flow is visualized with a high-speed camera and the images are processed in order to quantify the liquid sheet (LS) breakup length and width, as well as drop size. Results evidence that for lower Re_j, when the liquid sheet develops in a closed rim, the pre-impingement distance does not significantly influence the LS structure, or the characteristic size of droplets, which are mainly formed from capillary instabilities detaching from the bounding rim. However, if the Re_j keeps increasing, the LS rim begins opening at the bottom. Li and Ashgriz [1] observed a transition between a closed- and an open-rim LS between Re_j = 2000 and slightly less than 2500, however, we have observed a transition only above 2500. In fact, once the LS regime changes to that of an open rim, a higher l_{pi} leads to a shorter breakup length. This has implications relatively to the application of these sprays when short atomization distances are required. Relatively to the misalignment or skewness, it generates a radial moment in the development of the liquid sheet, leading to its rotation [2]. In terms of the effect of the pre-jet-impingement length and jet misalignment, the analysis of the experimental results can be synthesized in the following:

- the pre-jet-impingement distance l_{pi} produces a significant influence on the liquid sheet breakup length in the open-rim regime, but not in the closed-rim.
- in the open-rim regime, higher impingement distances between the nozzle exit and the impact location (l_{pi}), result in shorter breakup lengths, smaller drop sizes, and more droplets. The interpretation suggested is related with the relaxation of the jet velocity profile which is higher for larger l_{pi};
- the misalignment of the jets induces a rotation of the liquid sheet, enlargement of its breakup length and, consequently, thinning of its thickness. In the case of open-rim regime, this amplifies the instabilities and antecipates breakup, decreasing its length;

Further studies will consider the fundamental hydrodynamics associated with multijet impingement sprays with more than two jets.

[1] Li, R., Ashgriz, N. *Physics of Fluids* 18:087104 (2006)
[2] Gadgil, H. P., Raghunandan, B. N. *Atomization and Sprays* 19:1-18 (2009)

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