Novel Modifications of Twin-fluid Atomizers: Performance, Advantages and Drawbacks

J. Jedelsky* and M. Jicha
Faculty of Mechanical Engineering
Brno University of Technology
Technicka 2896/2, 616 69 Brno, Czech Republic

Abstract

In this work we studied a single-hole effervescent atomizer spraying light heating oil with air as an atomising medium in the "outside-in" gas injection configuration. We focused on modification of geometry of the atomizer exit section. Two atomizers, one with moderate, and one with intense helical swirler in front of the exit orifice were designed to expand the spray cone angle by a swirl of the gas-liquid mixture. Performance of the atomizer modifications were compared with a plain orifice atomizer. An experimental study of atomization process was made on cold test bench. Swirling the mixture led to a significant increase of the spray cone angle at low gas to liquid ratio by mass. An increase of the gas mass fraction in the mixture inhibits the swirl action on the spray shape. The swirl effect diminishes with GLR rising above 15 %. An atomizer with secondary air at the exit orifice and an atomizer with secondary air beyond the exit orifice were designed to reduce the droplet size in outer spray region. The secondary air at the exit orifice gave by 5 % lower overall Sauter mean diameter, using equal total amount of atomising air, compared to the plain orifice atomizer. The secondary air beyond the exit orifice did not bring any spray improvement but induced an undesirable contact of the liquid with the exit port wall.

Introduction

Effervescent atomizer belongs to twin-fluid atomizers with internal mixing and it is characterised by relatively simple construction. It produces fine spray at low pressure and with low amount of atomising gas [1]. Regardless of it there is still potential to improve atomization characteristics such as too narrow spray cone angle of the single-hole atomizer in combustion applications and a presence of large droplets in the spray border worsening exhaust gas emissions. Four new atomizers with modified exit ports were designed to address these subjects.

Materials and Methods

Experimental equipment includes effervescent atomizer, cold test bench with fluid supply system and Phase/Doppler Particle Analyzer. Description of our experimental facility and Dantec 1D P/DPA used for droplet size measurement can be found in [1].

A single-hole effervescent atomizer in outside-in gas injection configuration was used, see Fig. 1. Light heating oil (LHO) was atomized using an atomizing air. Several nozzles were designed:

- simple atomizer without swirler (P) for comparison of results, see Fig. 1,
- two atomizers with helical swirl insert: one with moderate swirler (I) and one with intense swirler (II) to extend the spray cone angle, see Fig. 2,
- one atomizer with introduction of the secondary air beyond the exit orifice (III) and one atomizer with secondary air at the exit orifice (VI) to reduce droplet size at spray edge.

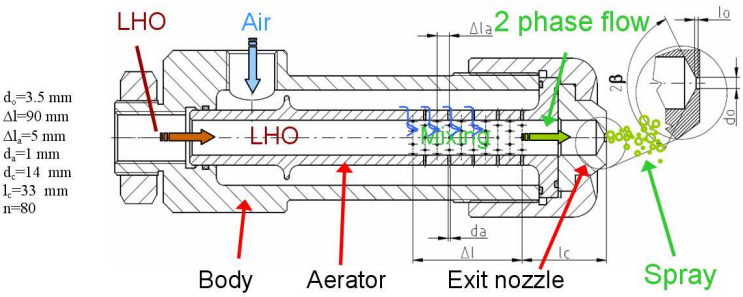

Figure 1. Plain-orifice atomizer (P) with dimensions

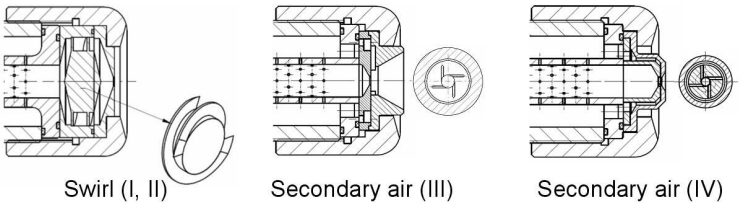

Figure 2. Newly designed atomizers

Results and Discussion

Spray cone angle (SCA) of three atomizers was evaluated using spray photography (Fig. 3). Atomizer P gives

* Corresponding author: jedelsky@fme.vutbr.cz

spray with max. cone half-angle 20° at GLR 10 %. Decrease in GLR leads to the SCA reduction and to a collapse of the SCA if no air used (GLR=0). Atomizers with moderate (I) and intense (II) swirler give wide spray from GLR=0. GLR increase reduces the cone angle as critical discharge disturbs the swirl motion.

Exemplary results of the spray measurement using P/DPA for atomizer P and IV at a distance of 150 mm downstream the exit orifice are shown on Fig. 4 left. Measured radial profiles of Sauter mean diameter, D_{32}, show inversely bell shaped course. The general tendency is the same for both the atomizers. The atomizer IV produces smaller droplets, mainly out of spray axis, than the atomizer P. It is due to an interaction of the liquid with the secondary air at the exit orifice edge.

Overall performance of the newly designed atomizers is shown in Fig. 4 right. To characterize the atomization quality by a single parameter, we introduced an Integral Sauter Mean Diameter, ID_{32}, which represents the whole spray at a certain cross-section perpendicular to the axis of the nozzle exit orifice [2]:

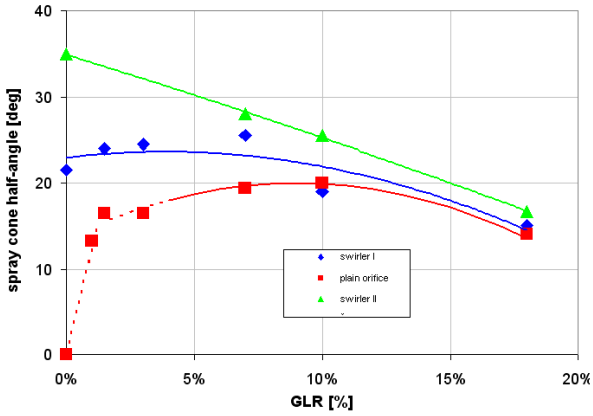

Figure 3. Influence of the mixture swirl on the spray cone half-angle.

$$ID_{32} = \frac{\sum_{i=2}^{n}\left(r_i \cdot D_{30,i}^3 \cdot f_i\right)}{\sum_{i=2}^{n}\left(r_i \cdot D_{20,i}^2 \cdot f_i\right)}. \qquad (1)$$

where $D_{30,i}$ and $D_{20,i}$ are the volumetric and surface diameters of drops measured at the radial position r_i. An ensemble of n drops is measured using P/DPA with drop arrival frequency f_i. The ID_{32} calculated from data measured in radial profiles of D_{32} is shown in Figure 4 right. The secondary air at the exit orifice (IV) gives the lowest ID_{32}, using the same total amount of atomising air. The secondary air beyond the exit orifice (III) (not shown here) did not bring any spray improvement while induced an undesirable contact of the liquid with exit port wall.

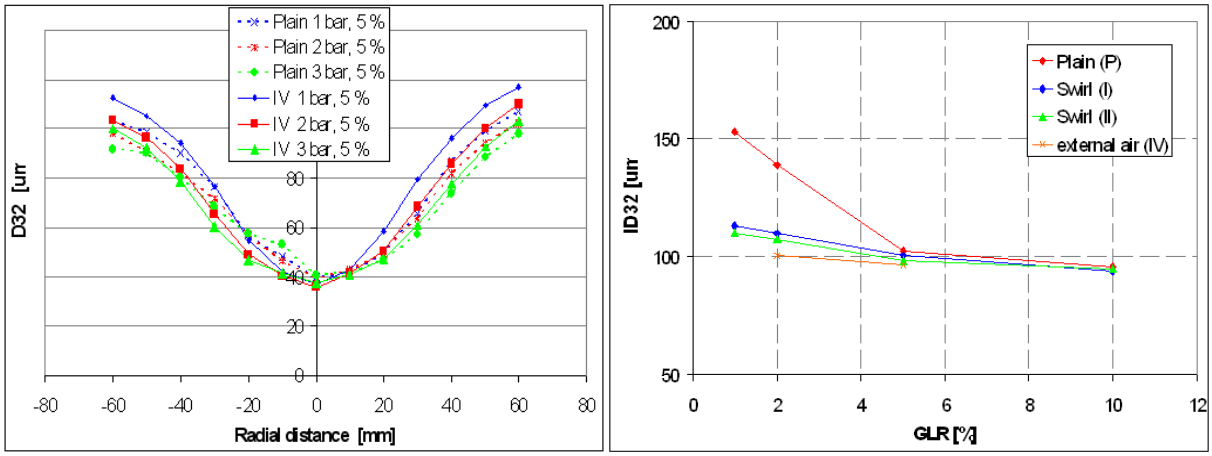

Figure 4. Influence of the air input pressure on ID_{32} for plain-orifice nozzle (P) and the nozzle with secondary air at the exit orifice (IV) at GLR 5 % (left); Influence of the GLR 5 % on ID_{32} at air input pressure 0.1 MPa (right).

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References

[1] Sovani, S. D., Sojka, P. E. and Lefebvre, A. H., *Progress in Energy and Combust. Sci.*, 483-521 (2001).
[2] Whitlow, J. D., and Lefebvre, A. H., *Atomization and Sprays*, 3: 137–155 (1993).
[3] Jedelsky, J., and Jicha, M., *Atomization and Sprays* 1:49-83 (2008).
[4] Jedelsky, J., Jicha, M., Slama, J. and Otahal, J., *Energy and Fuel* 23:6121-6130 (2009).