Characterization of fuel oil atomizers in industrial operation

Dorothée Chaillou, Vincent Alaterre, Xavier Paubel*, Bertrand Leroux, Rémi Tsiava
Air Liquide, Centre de recherche Claude-Delorme
1, Chemin de la Porte des Loges
78354 Jouy-en-Josas Cedex France

Abstract

This paper reports the methodology and main aspects considered to evaluate and optimize the design of an oil atomizer for industrial scale, from the operational conditions set up and spray characterization measurements reliability, to the impact for the particular application on oxy-combustion.

Introduction

Oxy-liquid fuel combustion has found many applications within the last years, especially in glass or metallurgy industries. The main purpose is obviously to increase the combustion temperature and subsequently to enhance thermal transfer. Heavy fuel oil combustion characteristics (efficiency, pollutant emissions…) are mainly piloted by atomization process [1]. In oxy-combustion of liquid fuel, atomization and vaporization time scales are key parameters, since vaporization of droplets is very short compared to combustion with air [2]. Thus, Air Liquide R&D is involved in the development of various types of atomizers (assisted and mechanical) dedicated to oxy-combustion. Since atomization quality depends on the operating conditions of the atomizers and on fuel oil properties (viscosity, density…) [3] [4], characterization of liquid fuel atomization phenomenon is essential to develop efficient atomizers. However, literature reveals a crucial lack of information on heavy fuel oil atomization characteristics, especially at industrial scale [5]. In this scope, Air Liquide decided to develop an atomization bench working in non-reactive conditions, with associated diagnostic devices (drop-size measurement and strobe light imaging for spray shape visualization) to study the sprays of fuel oil generated by atomizers and thus to optimize the design of atomizer (assisted and mechanical). In the present paper an optimisation of atomizer efficiency thanks to this experimental bench is presented.

Materials and Methods

Experiments are carried out in atmospheric atomisation bench. This installation consists of a tank of fuel oil feeding the atomizer spraying heavy fuel oil in an atomization chamber. Thanks to the large operating range of this pilot, various types of atomizers and operating conditions can be tested: fuel oil flow rate range extends from 25 kg/h to 1100 kg/h, with injection pressure up to 100 bar, and atomizing air flow rate ranges from 2 kg/h to 150 kg/h with injection pressure up to 10 bar. Thus, sprays from atomizers of nominal power up to 12 MW can be operated.

Spray characterization is performed thanks to optical access installed on each side of the atomization chamber for the crossing of laser beams used for different diagnostic devices, notably drop-size measurement and strobe light imaging. The drop-size measurement system is a Malvern Spraytec consisting of a transmitter sending a laser beam crossing perpendicularly the spray and of a receiver including a network of detectors collecting the diffracted rays by the contact with fuel oil droplets [6]. The diffraction angle of the incidental laser beam varies in a conversely proportional way with the size of the particles, this is why the signal diffracted by fuel oil particles is collected by a different detector according to the droplet size. The instrument is able to measure the droplet size in various locations of the spray (axial and radial measurements), the atomizer being mobile thanks to a two axes robot. The minimal uncertainty on the obtained results is conditioned by the correction of phenomena like beam steering, vignetting and multiple diffusion which can bring error on droplet size [7]. With associated software, included corrections, SMD, Dv50 and Dv90 are calculated. The SMD (Sauter Mean Diameter) represents the diameter of a droplet having the same volume/surface area ratio as the entire spray. The Dv50 and the Dv90 represent respectively the drop diameters such that 50% and 90% of total liquid volume is in drops of smaller diameter.

The strobe light imaging allows observing the structure of spray, enlightened by an impulsive laser. The corresponding sequence is recorded by a camera, whose opening is synchronized with the flash of the laser source. The characteristic time of the atomisation is several dozens of millisecond. In our case, the spray is enlightened during ten nanoseconds to get a snap shot of the atomization phenomenon. The camera acquires the diffusion signal of droplets enlightened by a 10 Hz laser. This instrument brings help in the characterization of the spray

* Corresponding author: xavier.paubel@airliquide.com

structure generated by an atomizer. It is indeed possible to assess the liquid core, the spray angle and the presence of big structures.

Results and Discussion

The atomization bench associated with drop-size measurement and strobe light imaging allows characterizing assisted or mechanical atomizers. The information on spray angle, obtained thanks to the strobe light imaging, permits to determine the maximal radial position possible for which drop-size measurement may be applied: it gives the spray boundaries. The liquid core length and spray structure give information on the atomization mode and performance of the studied atomizers.

In case of assisted atomization study, droplet size versus the ratio of atomizing gas and fuel oil mass flow rate (A/F) is obtained. Figure 1 represents, for two assisted atomizers, the droplet size (SMD) divided by an expected SMD_o versus the air/fuel ratio (A/F) divided by an expected air/fuel ratio ($(A/F)_o$) ; droplet sizes are measured here 680 mm downstream on the spray axis where liquid is fully atomized. As expected, the measurements show that an increase of air/fuel ratio implies a decrease of droplet size: the atomization becomes finer. This graph shows also that the atomization bench allows optimizing injector technology: for a given droplet size, the atomizing air percent is reduced with injector B compared to injector A: the energy efficiency is better.

Thanks to this atomization bench and its associated diagnostic devices, it is possible to characterize the atomizer technology effect on the atomization phase (spray structure and droplet size). This characterization allows the development and the optimization of assisted and mechanical atomizers before tests in reactive conditions.

References

[1] Gupta, A. K., Presser, C., Hodges, J. T. and Avedisian, C. T., *Journal of Propulsion and Power,* Vol. 12, N°3 (1996).

[2] Lacas, F., Leroux, B. and Darabiha, N., *Proceedings of the combustion institute*, Vol. 30, Issue 2, pp. 2037-2045 (2005).

[3] Chen, S. K., Lefebvre, A. H. and Rollbuhler, J., *Journal of Engineering for Gas Turbines and Power,* Vol. 114, pp. 97-103 (1992).

[4] Lorenzetto, G. and Lefebvre, A., *AIAA Journal,* Vol. 15, N°7, pp. 1006-1013 (1977).

[5] Costa, M., Costen, P. and Lockwood, F.C, *Combustion Science and Technology*, Vol. 75, pp. 129-154 (1991).

[6] Hirleman, E.D., *Part. Part. Syst. Char.,* 5 (1988).

[7] Dumouchel, C., Yongyingsakthavorn, P. and Cousin, J., *International Journal of Multiphase Fl*, Vol. 35 (2009).

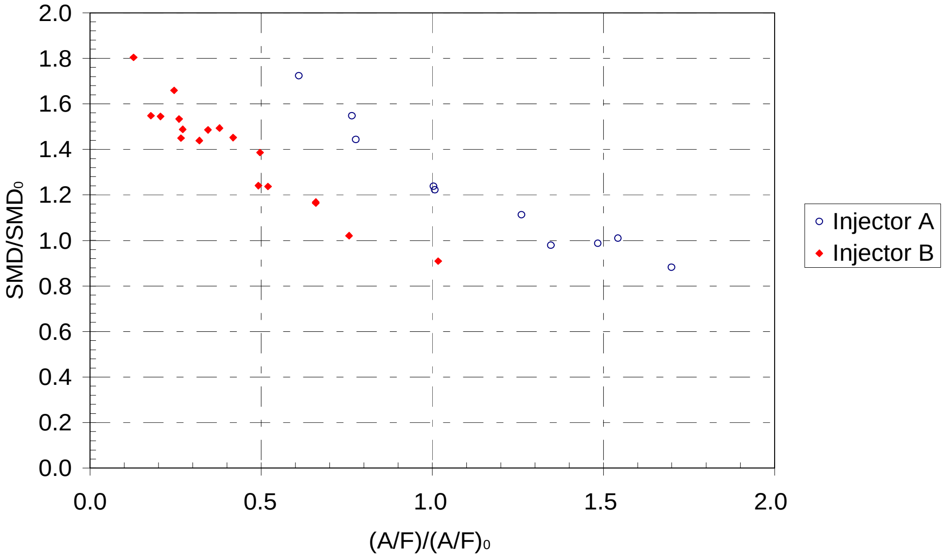

Figure 1. SMD versus Air/Fuel ratio