

Cold flow PIV and spray visualization experiments applied to the development of ALSTOM dual fuel gas turbine burners

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ALSTOM has been since long developing dual fuel gas turbine burners, capable to burn either natural gas or oil with the same hardware. This is done following a standard burner development process including a series of numerical investigations such as CFD and thermoacoustic modeling, accompanied by experiments both in cold conditions (water / wind tunnels) and with combustion (single / multi-burner under atmospheric / high pressure conditions), before the engine validation stage. Since oil combustion involves complex phenomena like spray formation and evaporation of single and multi phase fluids, for which satisfactory numerical modeling methods are still under development, experiments play a key role in the development process. In particular, a simplified experiment allowing early feedback to the development process would be the most desirable for an efficient burner development process.

In ALSTOM's labs a wind tunnel was therefore designed and built for spray investigation purposes. By running this tunnel with a mixture of air and SF₆, which has a density about 6 times higher than air, it is possible to simulate pressures of up to 8 bar under typical gas turbine pre-heating temperatures while operating the rig under cold and atmospheric pressure conditions. These operating conditions allow the required optical accessibility, flexibility and cost-effectiveness to be obtained. Fuel is simulated by a water/ethanol mixture which has a similar density to the oil/water emulsion used in the gas turbine. Full-scale burner models are used and the test conditions are chosen to match the fuel-to-combustion air momentum ratio of the gas turbine.

The importance of such testing, which is able to simulate an increased pressure as well as the interaction with the burner flow field, was confirmed by tests carried out with injection into still air/SF₆ mixture (pressure effect alone) or into flowing air without SF₆ (burner flow effect alone). These tests showed the strong influence of each of these two effects on the spray features, so that only by combining the two a representative characterization of the spray produced under gas turbine conditions can be achieved.

The test rig has full optical access through glass walls, while the burners are provided with plexiglass windows, to allow laser light sheet illumination and camera view for PIV tests. Due to the flow features, droplets are often impinging on the windows of the model and on the test rig walls, thereby posing a serious threat to the image quality. However, with the setup used, images of acceptable quality for PIV tests can still be obtained (Fig. 1.d), using the droplets as tracers to produce the velocity field of the liquid phase (Fig. 1.e-f). At the same time, the raw images produced for PIV processing represent Mie scattering of the

droplets and can therefore be used for spray visualization and characterization (Fig. 1.a-d).

Different liquid fuel injectors have been tested in the SF₆ test rig, and both the spray pattern (average image and RMS fluctuations, see Fig. 1.a-c) and its velocity field (see Fig. 1.e-f) were used to characterize the spray of each injector. By correlating this information with the results from combustion tests, it was possible to identify some spray features that have an impact on combustion behavior.

Injectors for wet oil operation show no influence of injector geometry on NO_x emissions, the NO_x level being mostly related to the effect of the water in the emulsion on flame kinetics. Instead, strong differences can be observed in the pulsation levels measured under the same operating conditions with different injectors, therefore injector optimization should be performed with the target of low pulsations operation to extend components lifetime.

The present study showed that, among the macroscopic spray features, the spray opening angle and the spray density along the axis appear to play a key role in the correlation with pulsation behavior. For the tested geometries, given a fixed injection position, a decrease in pulsation intensities appeared being associated with larger spray angles and smaller spray densities.

As a result, a screening of possible injector variants was performed and the test results allowed the down-selection of the most promising ones for further testing and a cost and risk reduction for the further development steps.

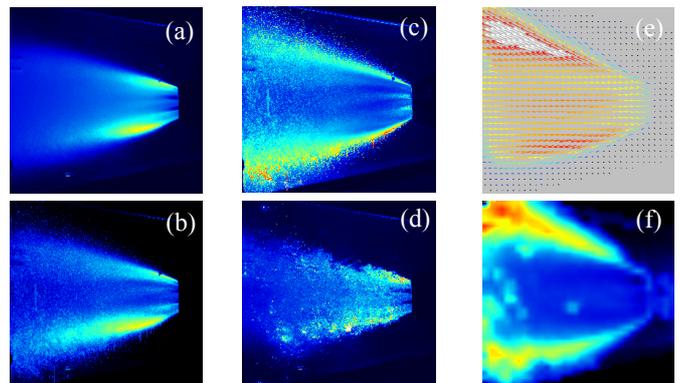


Fig. 1 Sample results from PIV / spray visualization test: average spray image (a), RMS spray image (b), RMS/average spray image (c), sample instantaneous spray image (d), average velocity vector field (e), and RMS velocity field (f).