VISUALISATION AND PHASE DOPPLER ANALYSIS (PDA) MEASUREMENTS OF OSCILLATING SPRAY PROPAGATION OF AN AIRBLAST ATOMISER AT ENGINE TYPICAL CONDITIONS

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New concepts for lean liquid fuelled gas turbine combustion require an exact knowledge of the atomisation process and the spray propagation in order to achieve a homogeneous lean mixture of fuel and air and resulting low NO_x-emissions[1]. However, well-mixed lean combustion tends to serious combustion oscillation. The optimisation of the atomiser therefore requires time-resolved investigation of the two-phase flow with respect to the interaction between combustion and atomisation process[2]. The present study focuses on phase locked visualization of the spray propagation and flame luminescence of an airblast atomiser in a single combustor rig at engine typical conditions. The transient spray propagation is additionally investigated via time resolved Phase Doppler Analysis (PDA) measurements in the reacting flow.

EXPERIMENTAL

To investigate the spray propagation of a prefilming airblast atomiser at realistic conditions, a model combustor consisting of two quartz glass tubes confined by a pressure vessel with two plain quartz glass windows for excellent optical access has been utilised (Fig.1)[3].

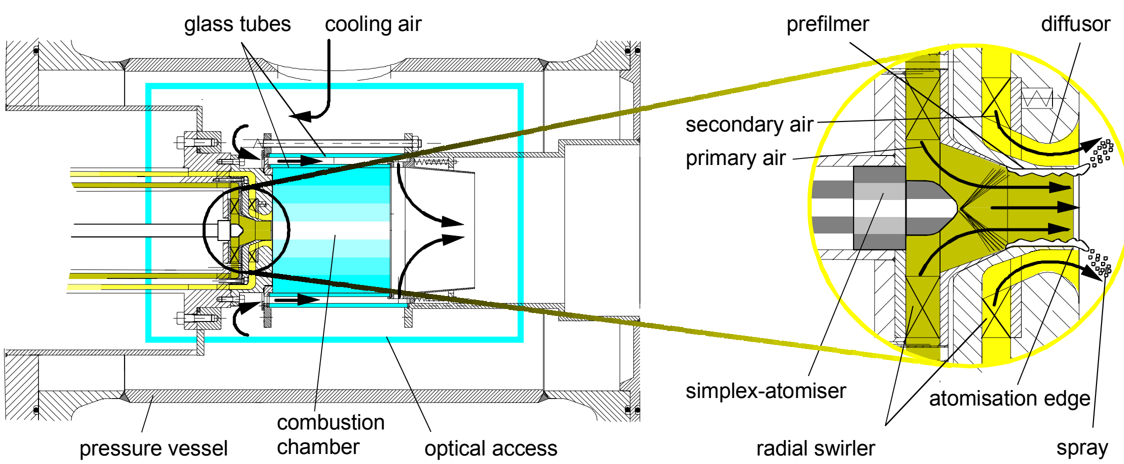


Fig. 1: Cross-sectional view of the high pressure test rig including the model combustor

The liquid fuel is spread onto the prefilmer by a simplex atomiser. This fuel film is shear driven transported to the atomisation edge, where it disintegrates and forms the spray.

The test rig is part of the high pressure, high temperature test facility (HDT) of the Institute for Thermal Turbomachinery (ITS). With maximum pressure of 1 MPa and a maximum combustor inlet temperature of 1100 K the facility offers test conditions comparable to those of aeroengines at cruise condition.

Fig. 2 shows the optical test set-up to investigate the two-phase flow inside the model combustor by means of the Laser Light Sheet technique. The Light sheet is directed through the right optical access to the combustor axis. For the investigation a pulsed Nd-Yag laser is used for illumination. At a pulse frequency of 10 Hz the laser gives pulses of 140 mJ energy at a pulse length of 15ns. A two dimensional image of the spray is captured by a fast shutter CCD-Camera wit a resolution of 1280 x 1024 pixel positioned at an off-axis angle of 72°. A microphone close to the pressure vessel measures the pressure oscillations of the combustion process. The oscillating frequency is determined by FFT analysis. The signal is band pass filtered with respect to the dominant frequency. Finally a timing unit creates a trigger signal shifted from 0° to 360° relative to the rising edge of the dominant frequency.

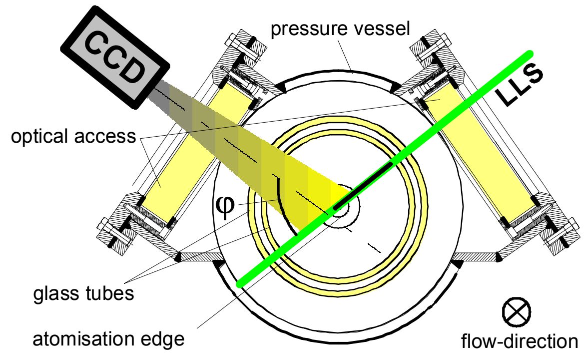
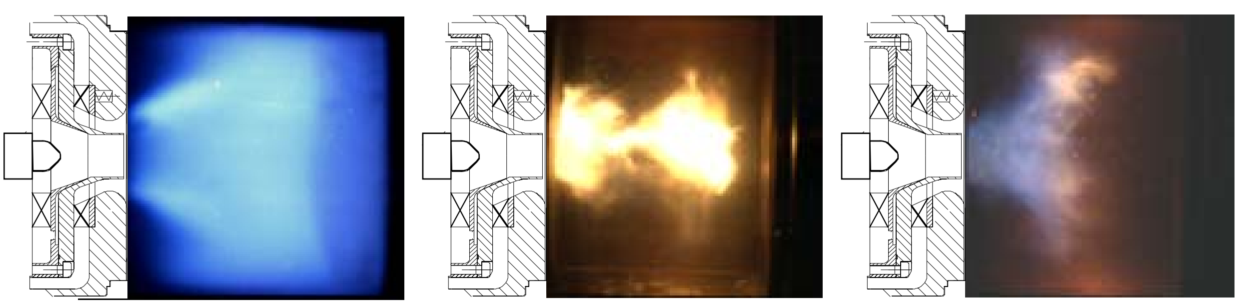


Fig. 2 Cross section of the combustor pressure vessel

RESULTS

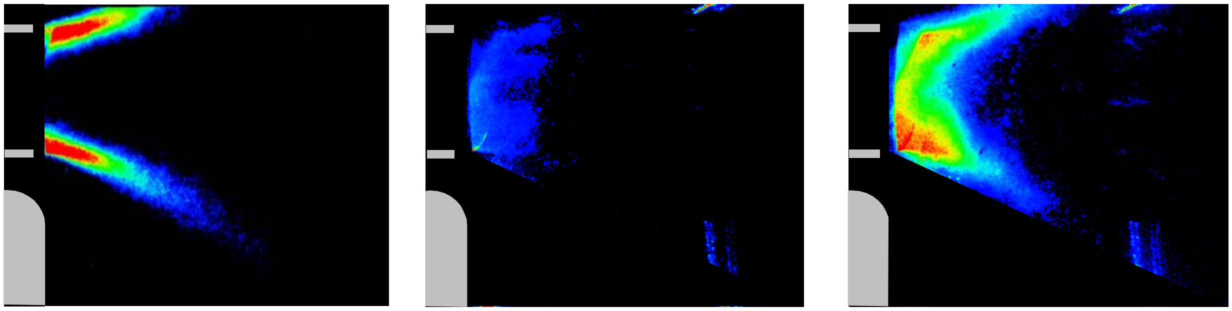
Depending on the fuel-air ratio, the inlet temperature and the inlet pressure, the model combustor exhibits large pressure oscillations. In Fig. 3 the first left image shows a stationary situation at 0.4 MPa and λ=3.0. Increasing the fuel mass flow and the pressure, the combustion process oscillates with an oscillation frequency of 620 Hz (0.8 MPa, T_{inlet}=573K, λ=2.0) . The second and third images of Fig. 3 show two typical situations, captured at two different moments at the same condition.



0.4MPa, λ=3.0, non oscillating 0.8 MPa, λ=2.0, oscillating 0.8 MPa, λ=2.0, oscillating

Fig. 3: Images of flame luminescence at different operating conditions

The images in Fig. 4 show the average droplet distribution of 150 images. The acquisition of the images is phase locked at oscillating conditions. The first image shows the non-oscillating case. The droplets propagate in a dense spray, in the centre of the atomiser no fuel droplets appear.



0.4MPa, λ=3.0, non oscillating 0.8 MPa, λ=2.5, dt=300ns 0.8 MPa, λ=2.5, dt=500ns

Fig. 3: Average droplet distribution at different operating conditions

The second and third image of Fig. 4 shows the average droplet distribution at the same condition at two different times relative to the pressure oscillation. The overall time duration of one cycle is about 1600 ns. Typical for the oscillation is the presence of fuel close on the axis of the combustor.

The visualisation of the transient spray propagation show the strong influence of the combustor oscillation on the performance of the airblast atomiser and visa versa. The time resolved PDA measurements enable to quantify the influence of the pressure oscillation on the velocity and size of the droplets.

REFERENCES

[1] Santavicca, D.A., Steinberger, R.L., Gibbons, K.A., Citeno, J.V., Mills, S.
The Effect of Incomplete Fuel-Air Mixing on the Lean Limit and Emissions Characteristics of a Lean Prevaporized Premixed (LPP) combustor, *AGARD Conference Proc No 536, AGARD Meeting on 'Fuels and Combustion Technology for Advanced Aircraft Engines'*, May 1993

[2] McDonell, V.G., Adachi, M., Samuelsen, G.S.
Structure of Reacting and Non-reacting Swirling Air-Assisted Sprays. *Combustion Science and Technology*, Vol. 82, pp 225-248, 1992

[3] R. Meier, K. Merkle, G. Maier, N. Zarzalis, W. Leukel, S. Wittig,
Developement of an Improved Prefilming Airblast Atomizer for Gas Turbine Application*: 5th Annual Conference on Liquid Atomization and Spray System*, 5-7 July, 1999, Toulouse, France