Measurement of Initial Conditions of a Kerosene Spray from a Generic Aeroengine Injector at Elevated Pressure

S. Freitag*, U. Meier, J. Heinze, T. Behrendt and C. Hassa
German Aerospace Center - DLR, Institute of Propulsion Technology
Linder Höhe, 51147 Cologne, Germany

Abstract

Ab initio prediction of aeroengine sprays at realistic conditions is currently not feasible and will remain so for a significant time to come. As a partial solution to the problem, experimental data are generated to validate advanced combustion codes. For that purpose a generic injector was built and operated in an optical single sector combustor. Phase Doppler Anemometry and Mie Scattering were used. The in house algorithm that performs the on line measurement of the measurement volume was modified to suit the experimental setup. Measurements were performed at 4bar and 10bar. Good mass flux density profiles can be obtained within the lift-off distance of the flame.

Introduction

European aviation has pledged to reach the ACARE goals of environmental compatibility in the year 2020. The goal of reduction of NO_x by 80% must be reached by improved combustor technology. In view of the time required to achieve the necessary technological readyness, the transfer of a significant part of the development process into computer simulation is a must. The biggest impediment to that is the unavailability of reliable methods for spray prediction. Although with Level Set or Volume of Fluid, methods exist that can predict atomization, computers are just not quick enough today to calculate through the atomization process at the small scales that are created by modern air blast atomizers for aeroengines. Hence intermediate solutions have to be pursued and this contribution is part of such an approach. The spray initial conditions are measured for a generic atomizer that exhibits a spray similar to an aeroengine spray but without the features assuring airworthyness. With these measurements incorporated in the combustion codes as initial conditions, their ability to reproduce the spray combustion in a generic commbustor at relevant conditions is tested.

Materials and Methods

The injector was operated in the Single Sector Combustor (SSC). The combustion chamber is schematically shown in Fig. 1. It features a square cross section of 102 x 102 mm and a length of 264 mm. Electrically preheated compressed primary air – shown in yellow – is supplied to the plenum upstream from the combustion chamber. Additional preheated air is diverted from the primary air supply and guided to the windows for cooling. Burner and window cooling air are both controlled by sonic nozzles. The combustor pressure is controlled by another sonic nozzle forming the choked exit of the combustor, along with additional cooling air (blue) which enters the flame tube just upstream from the exit, after cooling the outside of the windows in the optical section. Figure 2 shows a schematic view of the burner. The two air flows are co-rotating. Kerosene is supplied by two opposite fuel lines to an annular fuel gallery, and from there to a vertical slot through a circular array of orifices. The pressure drop across these metering holes, along with the length of the vertical slot, results in a good circumferential homogeneity of the fuel as it exits the end of the slot. For the measurements, a Dantec PDA was used. Due to restrictions in optical accessibility, a 2-D setup was chosen. The geometry was optimized near Brewsters angle to achieve good signal to noise and robustness against reflected signals as well as low sensibility towards refractive index variations. A small measurement volume was created by the use of beam extender before the front lens to extend the applicability as far as possible into the dense spray region. A 5 Watt laser was used to achieve independence of measured SMD's from Laser power. The 3-D in house algorithm of Behrendt and Hassa, [1] was adapted to a 2-D setup and modified to take into account the geometrical conditions of the experimental rig. For Mie scattering, pulsed light sheets from a frequency doubled Nd:Yag at 532 nm were used.

Results and Discussion

Fig. 3 shows a photograph of the primary zone of the combustor at the experimental condition of 4bar. As

* Corresponding author: stefan.freitag@dlr.de

can be seen, the flame is lifted and the Mie scattering displays a homogeneous ring of liquid fuel, which has not yet significantly dispersed. Fig. 4 shows a plot of the axial fuel flux. The first attempt to measure the flux was made at 7mm behind the atomizer. But the isolines show, that maximum concentration is measured at z = 10mm and the maximum of the integrated distribution is only reached at z = 15mm. Here comparison with the litered mass flow yields 87 % of the litered value. Of course the spray has already partially evaporated such that this comparison is only a measure of plausibility. The reason for the problem in measuring the flux early on is the good atomization, which is already realized at 4 bar with SMD' s around 15 µm, which lead to high spatial concentrations of droplets, such that the maximum of the Mie scattering signal and the maximum of the fuel flux measured by PDA do not coincide at z = 7 mm. A construction of the spray at 7 mm therefore requires combination of PDA and Mie data. Nevertheless we believe, that the results represent what can be currently achieved with commercial equipment.

Acknowledgement

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References

[1] Behrendt, T., and Hassa, C., *AGARD Conference* proceedings 598, paper Nr. 5 (1997).

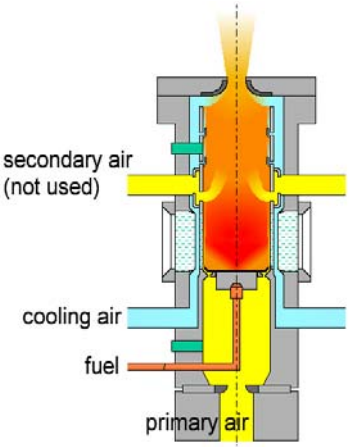

Fig. 1 Combustion chamber

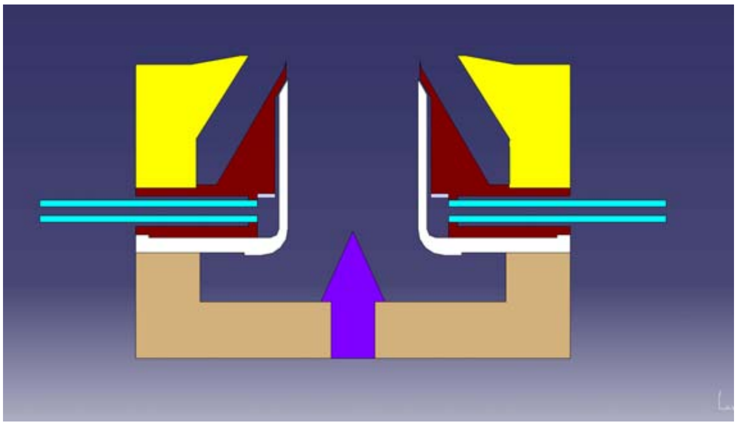

Fig. 2 Schematic view of the burner

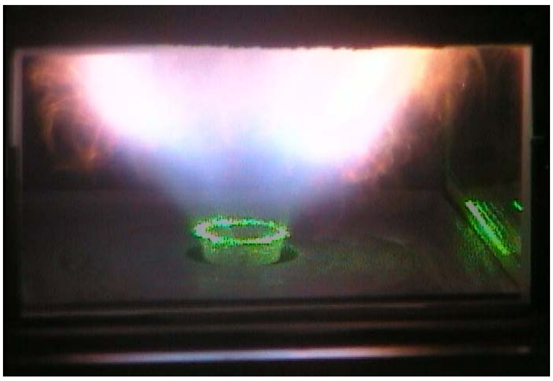

Fig. 3 Photograph of the primary zone

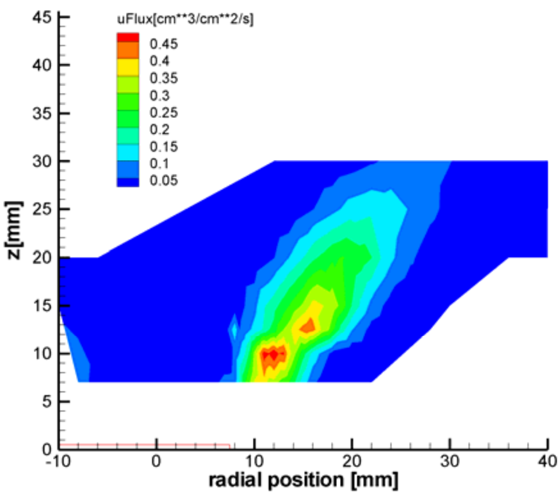

Fig. 4 Plot of the axial fuel flux