Effect of the initial droplet size distribution of the liquid phase combined with transport phenomena on the resulting airblast spray in the far field

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Abstract

Liquid-fuelled turbomachines for propulsion and power made great improvements in terms of overall efficiency and reduction of pollutant emissions over the last two decades. The main technology trends were a better atomisation using airblast injectors, a stronger pressure ratio and a higher combustor inlet air temperature acting on both refined spray and rapid evaporation (Lefebvre, 1989 and Faeth, 1977), and an operation in the lean combustion domain to obtain the right balance between thermal efficiency and pollutant emissions.

However, at such levels of pressure and temperature, the slightest injection fluctuation may have a dramatic effect on the combustion stability, with the risk to trigger a thermo-acoustic instability, interfere with the performance of the machine and/or provoke structural damages. The combustor is tuned during the design phase iterating with a trial-and-error session so that combustion remains steady at operation. But transients or unexpected events such as a partially plugged injector may still trigger a combustion instability. The research effort focuses on a better understanding of the physics of the injection, in order to provide design guidelines based on a rational approach, and also develop active control strategies able to maintain steady state combustion.

This study reports on the combined effects of a modulated injection of liquid in presence of a strong thermoacoustic resonance. The atomisation is being pulsed by the fluctuating air velocity, the resulting spray feeding cyclically the flame front while being transported by the flow. This process contributes to the enhancement of the aero-thermo-acoustic coupling. One combustion control strategy consists in acting in real time on the liquid injection, in order to act in phase-opposition with the acoustic pressure and thus damp the instability. The influence of the unsteady atomisation process and two-phase flow transport are taken into account. The idea is to assess the levels of fluctuation on the injection and time-shifts required to damp as much as possible the pulsating spray effect.

The reference test case is a simplified air-blast injector, a flat prefilmer atomising kerosene at intermediate pressure and room temperature (Bhayaraju, ICLASS 06-06-073, 2006), where evaporation is neglected. A one-dimensional model where the particle transport is based on the Bousinesq-Basset-Oseen equation describes the spray behaviour as a function of both initial distribution and air velocity fluctuation. The model is tuned to match the droplet size measurements performed on the DLR fuel spray test rig. The orders of magnitude of air flow fluctuation and their effect of the injection are inspired from Giuliani et al, 2002, Eckstein et al, 2003 and Gajan et al., 2007.

The transport model basics are discussed. The simplification concerning the introduction of the liquid phase already fully atomised in the computational domain is assessed. is underlined.

This research aims at the refined understanding and description of unsteady airblast atomisation. It is financed by the Austrian Science Fund (FWF) and is a joint study with the DLR Cologne.

Keywords
Airblast atomisation, particle transport model, unsteady flow, isothermal

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