R. Payri, F.J. Salvador, M. Carreres, C. Moreno-Montagud, “*Primary spray breakup modelling of prefilming airblast atomizers in aeronautical burners*”

ABSTRACT

The air traffic increase raises concerns on the impact of pollutants on public health and climate change. ACARE defined challenging goals with 5% reduction in CO_2 aircraft emissions per passenger-kilometre and a 90% reduction in NOx in the 2000-2050 period.

Fuel injection plays a key role in this challenge. Liquid fuel is injected into a gas turbine combustion chamber through an atomizer. Great effort is placed to ensure the atomizers generate small droplets, promoting fast evaporation and homogeneous mixtures, which in turn increase combustion efficiency and reduce pollutant emissions. Prefilming airblast atomizers are becoming a widely used solution in state-of-the-art aero engines. In these atomizers, fuel is deposited on a prefilmer onto which it flows in the shape of a film driven by a surrounding high-velocity airstream, until it reaches the atomizing edge where it is destabilized and breaks up into ligaments and droplets.

The usual approach to simulate fuel mixing and combustion in the aviation industry is to rely on low-fidelity RANS or LES simulations coupled to a phenomenological model for the spray breakup, offering a compromise between accuracy and computational cost. This kind of models exist in commercial CFD software, but they are generally based on a theoretical derivation from instability analysis, not being fully representative of airblast atomization and thus requiring heavy calibration. Hence, there is a need for updated atomization phenomenological models for this application.

In this regard, experimental works so far have only been able to provide reliable quantitative data in the secondary atomization region (related to the Far-field, far from the disturbance that produces liquid breakup), mostly addressing primary atomization (related to the Near-field, close to the source of breakup) only from a qualitative standpoint.

The proposed methodology, presented in the frame of a Horizon2020-CleanSky2 project (H2020-CS2-CFP07-2017-02 GA 821418 “ESTiMatE”), is based on DNS-type breakup simulations that can provide detailed information on primary breakup that experiments cannot resolve. The use of HPC resources made it possible to implement a novel inlet boundary condition for the DNS study of prefilming airblast atomization that allows accounting not only for the inflow turbulence but also for the temporal evolution of the liquid film thickness at the DNS inlet. The methodology implies the resolution of subsequent single-phase LES, two-phase flow LES and two-phase flow DNS. Results for a widely known operating condition show a different degree of atomization when the liquid film thickness evolution is accounted for than the one obtained using a constant liquid film thickness at the domain inlet.

The exploitation of the implemented methodology with a parametric study containing different operating conditions representative of aero engine operation should allow deriving a breakup phenomenological model specific for airblast injectors. Replacing the theoretical models currently used by manufacturers in their lower fidelity simulations will undoubtedly increase the reliability of their outcomes, constituting a basic tool for the improvement of the current technical solutions and enabling for cleaner and more sustainable aircraft engines.