PhD Position (3 Years)

Modelling and simulation of near-wall combustor cooling in VHBR engines

Pollutant formation, in particular nitric oxides (NOx), unburnt hydrocarbons, (UHC), carbon monoxide (CO) and particulate matter and smoke (PM) occurs in different measure during engine operations depending on the local stoichiometric conditions and on the pressure and temperature determined by the thrust requirements. In particular in RQL (Rich Quench Lean) the requirement to prolong residence times to promote the burn-off of PM competes with the effort to minimise the same residence time in an attempt to reduce NOx formation. In large turbo-fan engines with high to very high bypass ratio (VHBR) the temperature at the combustor exit remains relatively high and in an attempt to reduce it to levels falling below the critical threshold for the onset of the thermal NOx reaction path, the liner cooling air is reduced to a minium. The presence of a strong swirling flow in the main body of the combustor induces hydrodynamic disturbances which disrupt the labile cooling layer and allow the flame to approach the liner wall. In the presence of fuel-rich gases, as occurring in the primary region of RQL combustor, the cooling air also affects the reaction patterns by providing oxidant for high-temperature combustion, thus increasing the formation of NOx in the forward part of the combustion chamber.

Aim of the proposed research is to develop an efficient simulation strategy within the in-house code PRECISE-UNS which allows performing wall-resolved LES computations accounting for both cooling film dynamics and for the interactions of the wall region with the core flow turbulence. The efficient coupling of differently resolved computational regions is necessary for carrying out sensitivity studies and examining the dependence of mixing and reaction patterns on new control variables to accurately describe the chemistry-turbulence interaction in presence of cooling. This will be in turn the starting point for an investigation of finite-rate chemistry effects involved in CO and UHC formation. The proposed work will benefit from input and exchange with ongoing and planned related projects and from high quality measurements carried out also at high pressure at both RSM (TU-DA) and DLR-Cologne for the first time available on a quantitative basis. The expected outcome is an improved understanding of the cooling film interactions with the core flow and hence the possibility of identifying important control

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parameters for an effective liner cooling design and obtain an improved control of pollutant emissions deriving from near-wall dynamics.

During his/her PhD, the successful candidate will:

- seek and implement an optimal strategy for performing locally resolved Large Eddy Simulation of the near-wall region in presence of effusion cooling using the in-house CFD solver PRECISE-UNS;
- investigate the effects of different cooling schemes on the mixing and reaction patterns adopting the currently available turbulent-chemistry interaction (TCI) models;
- seek to identify viable extensions of the commonly used TCI by means of additional control variables and explicitly accounting for finite rate chemistry effects;
- validate the simulation strategy in a practical combustor configuration.

The ideal candidate:

- possesses a Degree in Engineering, Physics or Mathematics;
- has a strong background in Thermofluids Science and/or turbulent reacting flows;
- is highly proficient in FORTRAN;
- has a strong interest in Numerical Methods and Computational Fluid Dynamics.

The bursary is offered on a three-year basis and is funded by Rolls-Royce in the Rolls-Royce University Technology Center for Combustor-Turbine Interaction at Darmstadt Technical University.

For further details please contact Prof. F. di Mare at the address provided.