Modelling of small gas turbine engine CO emissions based on reactor network

I.A Zubrilin [1]., S.G. Matveev [1], A. Marrone [2], D.M. Pastrone [2]

[1]*Samara National Research University, Russia*
[2]*Politecnico of Turin, Italy*

Thanks to the development of the computational power and sources it was possible, across the years, to simulate in greater detail the combustion process that occurs in reality by the using and the combination of different models for the chemical-kinetic and turbulence phenomena. The main point of focus is the prediction of the pollutant emissions of these combustors, like NOx and CO, and also the concentration of other species, like UHC, responsible of particulate emissions.

The combustor chamber of the small-scale turbojet SR-30 engine (Turbine Technologies) is here analyzed. The experimental values of pollutant emissions measured at different regimes of rotational speed are compared with numerical results obtained using different CFD methods.

The interaction between turbulence and chemistry for the air/fuel mixture is the partially-premixed combustion, where the species are not perfectly mixed before combustion. A first approach here used is the Flamelet Generated Manifold (FGM), that is a chemistry reduction technique based on the analysis of the flame front and the resolution of the structure of flame stretch. The FGM, combined with the Probability Density Function (PDF) method, responsible of the stochastic description of the turbulence-chemistry interaction, that totally replaces the deterministic one, allows to evaluate NOx emissions, described by the thermal mechanism of Zeldovich. In the present study several parameters (i.e. the mesh size, the approaches used to evaluate the concentration of O and OH, and the dimension of the mean diameter of the fuel particles distributions at the injector) are changed to perform the simulations. When a proper mesh size is selected, the fuel particles size appears to be the parameter that more affects the values of NOx and allows to have a good match of numerical values and experimental data.

A different approach, i.e. the Reactor Network method (RN), instead is used to evaluate CO emissions. This method is based on a subdivision of the combustor volume into a given number of reactors: in this work all the reactors are perfectly stirred ones. Each reactor is characterized by a specific fuel fraction and a proper residence time. Typically, increasing the number of reactors allows to describe much better the experimental results.

The flow field during these simulations is defined by the RANS equations that describe the mean flow field, avoiding the so high computational cost of Direct Numerical Simulations (DNS). Finally Large Eddy Simulation (LES) is considered as a further method to obtain more accurate results, to be compared to the ones previously obtained.

This work was supported by the Ministry of education and science of the Russian Federation in the framework of the implementation of the Program "Research and development on priority directions of scientific-technological complex of Russia for 2014-2020" (RFMEFI58716X0033).