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Combustion Simulation with Particular Reference to Green Aviation

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With the fast development of the aviation transportation, the emission (NOx, CO, UHC, CO2, smoke particle and contrails) of the civil aeroengine using the hydrocarbon fuel has damaged the environment tremendously. Especially, the NOx and CO2 have a big contribution to the global warming. In order to greatly reduce the damage of the civil aeroengine to the environment, ACARE (Advisory Council for Aeronautical Research in Europe) has published the 2020 annual target, i.e., the 80 percents reduction of NOx, 50 percents reduction of CO2 per passenger per kilometer, and 20 db reduction of the noise. In order to achieve the ACARE 2020 annual target, one key technology is low emission combustion technology.

Experimental research, theoretical analysis and numerical simulation are involved in liquid fuel injection and spray combustion research. With the increasing computing speed and storage capacity, it has become possible to study injection with the aid of Computational Fluid Dynamics (CFD), by which we can have deeper understanding of the complex flow mechanism through injection and atomization process.

This presentation addresses a tool used for prediction and understanding of combustion mechanisms. It is a parallel CFD solver, featured using full compressible Navier-Stokes equations with finite-rate chemistry reaction. The high-order Taylor-Galerkin scheme based on unstructured meshes is used to meet the demand for Large Eddy Simulation of turbulent flow in complex geometry [1], while the thickened flame model for turbulent premixed and non-premixed flame is implemented in the solver [2-3]. Also, a moving particle semi-implicit (MPS) method is utilized to model atomization, to provide the rules of the droplet diameter and distribution [4].

With the constant pursuit of aircraft performance, the aero-engine design rises toward the high temperature, high combustion efficiency, low emission and other requirement, which makes the conventional combustor become more and more difficult in design improving. In this context, the concept of Trapped Vortex Combustor (TVC) has the character of staged combustion, and is composed of cavity and mainstream area basically. When fluid flows over a cavity, vortices can be trapped by reason of viscosity and there comes the recirculation zone. Inspired by this phenomenon, researchers concluded the ‘trapped-vortex stability’ theory and applied it to the combustor design. The TVC has high combustion efficiency, low lean-blowout limit and small total pressure loss.

Because of relatively simpler structure, lower pollution emissions and other characteristics, the TVC has been investigated by many researchers [5-6]. In this presentation, numerical simulation was carried out under different working conditions on TVC models without and with the flame joint and flow stabilization device. The impact for the two models' distribution of cold and hot flow field, total pressure loss, and thermal pollutant discharge was analyzed. The results are hoped to provide reference for the design refinement and performance evaluations of a TVC.

Further, according to the latest open research results [7-10], the method of Lean direct injection (LDI) combustion scheme has been proposed to reduce NOx emission under the condition of high pressure and high temperature combustor. In this presentation, large eddy simulation (LES) of turbulent combustion in a model LDI combustor is addressed.

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