Understanding Complex Phenomena in Air-Breathing Engines using Computational Fluid Dynamics

C. Fureby
Defence Security Systems Technology, The Swedish Defence Research Agency – FOI,
SE 147 25 Tumba, Stockholm, Sweden

Conventional air-breathing propulsion systems consist of turboshaft engines, turbofan engines, and afterburning turbojet engines for military aircraft. These engine systems mainly rely on annular combustors with multiple burners sharing a common fuel supply line, typically burning kerosene. Such engines are technically complicated, with complex geometries and moving components, and are sensitive to combustion instabilities. They are limited to Mach numbers below 3 since the compressed air through the engine reaches such temperatures that the compressor stage fan blades begin to fail. For higher flight speeds ramjet engines may be used: Ramjets use air-in-takes that guarantees that the supersonic flow is decelerated to a subsonic flow before the combustor, where fuel is injected and combustion takes place. In excess of Mach 5, extreme temperatures and pressure losses occur when decelerating the supersonic airflow to subsonic conditions, making ramjets impossible to use. Instead supersonic combustion ramjets (scramjets), in which the combustion occurs in a supersonic flow, may be used. Scramjets have great potential, but the aerothermodynamics involved is very complicated and not yet fully understood.

Here, the use of Computational Fluid Dynamics (CFD), and in particular Large Eddy Simulation (LES), as a tool for examining and proposing improvements to air-breathing engines will be discussed. For conventional air-breathing propulsion systems, state-of-the art CFD models will provide means of improving existing engine concepts and propose solutions to technical problems. For emerging supersonic and hypersonic air-breathing propulsion systems, high-fidelity CFD models provides exclusive means of developing new knowledge to guide the development and design of novel engine concepts such as scramjets and dual mode ramjets. Critical issues of conventional air-breathing engines include thermo-acoustic instabilities, the occurrence of which can critically damage an engine, and emissions, limited by ever-stricter regulations. These topics along with possible remedies examined using LES will be discussed together with the use of state-of-the-art LES to study scramjet and dual mode ramjet engines.