Part II
Combustion

This part of the book dwells on experimental, theoretical and numerical description of gaseous combustion in gas turbine combustors. It includes the development of methods involving reduced reaction mechanisms for complex fuels, soot modeling and the formulation of appropriate turbulence-chemistry interaction models for different combustion regimes. In particular, innovative measurement techniques allow time-resolved characterization of flame stability and extinction behavior and generation of comprehensive experimental data.

In this context Chap. 4 presents the designed experiments and measurement techniques for improving the understanding in turbulent combustion with a focus on turbulent flow and scalar fields as well as on their mutual interactions. The results are restricted to generic gaseous turbulent flames that feature different characteristics important to practical applications. They include combined scalar and flow measurements that can significantly improve the understanding of turbulence-chemistry interactions. Further achievements based on recently developed high-speed laser imaging are presented that complement methods at low repetition rate, commonly used to generate statistical moments and probability density functions.

Despite permanently growing computer power, the simulation of a reaction–diffusion-convection system involving a large scale chemical combustion mechanism is still far from reach. However, the prediction of minor species, e.g. soot, NO_x, and other pollutants, needs detailed mechanisms. Chapter 5 focusses on an effective dimension reduction of chemical combustion mechanisms. This is firstly based on an efficient use of the intrinsic low dimensional manifold method, and finally on optimization methods.

In Chap. 6 three different aspects of Large Eddy Simulation (LES) of combustion processes are covered using tabulated chemistry models in the line of the Flamelet-Generated Manifold approach (FGM) to describe the chemical reactions occurring in gas turbines. These are the extension of the FGM to describe pollutants such as NO_x and CO, the "Transported Filtered Density Function" method (Transported FDF), and the "Artificially Thickened Flame" (ATF) model. They have been analyzed and validated in various generic combustion systems.

Soot resulting from combustion processes is known to have a negative impact on health and environment. It also may lead to material damages especially in gas turbines. Therefore a deeper insight in the processes leading to the formation and consumption of the soot precursors and soot particles is needed. Chapter 7 dwells on describing these processes in the gas and the particle phase and provides mathematical models for simulating soot formation in complex technical systems such as gas turbines using LES.

Focusing on premixed combustion, Chap. 8 uses a description following a two-phase flow where the flame is modeled as a non-material interface. This induces jumps in velocity and pressure at the interface, which depend on the density ratio. In classical numerical methods for single-phase flows, such as finite volume, it is difficult to represent jumps accurately and stable, i.e. without oscillations, at the same time. In this chapter an extension to the Discontinuous Galerkin method is presented which is able to exactly represent jumps, with sub-cell accuracy.