Experiments in Turbulent Combustion

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Preamble

The aim of this lecture note is to present state-of-the-art experiments in turbulent combustion. The lecture is restricted to generic gaseous turbulent flames that feature different characteristics important to practical applications. The methods presented here are feasible to study boundary conditions, flow and scalar fields and are based all on interactions between laser light and matter. Basic knowledge of fundamentals such as quantum mechanics, molecular structure and radiation is presumed.

Following a brief introduction, generic target flames from simple to complex are exemplified. This selection of generic configurations, of course, is far from complete. Chapter 3 and 4 introduce to most popular flow and scalar measurement techniques. At the end of each of these two chapters exemplary applications of the methods are presented. Chapter 5 provides an introduction to combined scalar/flow measurements that can significantly improve our understanding of mutual interaction between chemical reactions and turbulent fluid flow. In chapter 6 new developments based on high-repetition-rate imaging are discussed. These diagnostics complement methods at low repetition rate commonly used to generate an understanding by statistical moments and probability density functions. High repetition rate imaging techniques presently are an emerging field. Although the most recent developments are included to this chapter, near-future progress in this field will lead to even more interesting insights into combustion phenomena. Due to the important role of numerical simulation in designing future combustion technologies, the final chapter 7 reviews some aspects of how experimental and numerical results compare.

1. Introduction to experimental combustion research

Turbulent combustion is the backbone of primary energy conversion. Although it is desirable that regenerative energy conversion processes such as solar or wind energy gain in their weight, combustion will keep its dominant role in the foreseeable future. This fact and recent public disputes on global change enforce that turbulent combustion processes in their various applications such as electrical power and heat generation, propulsion and mobility must be further improved in terms of efficiency and pollutant emissions.

Different pathways exist to advance combustion technologies. Figure 1.1 highlights the role of experimental methodologies. Experiments may serve either in a **direct** manner to measure key-quantities of a practical combustion process for subsequent improvements or experimental studies serve in an **indirect** way to support a mathematical/numerical model of the combustion process to be designed in future. Figure 1.1 additionally shows that experimental studies can gain from numerical modelling and numerical recipes. This interplay between experiments and numerical simulation will be touched in chapter 7 whereas the impact of numerical procedures on experimental methodologies is due in data post-processing strategies.

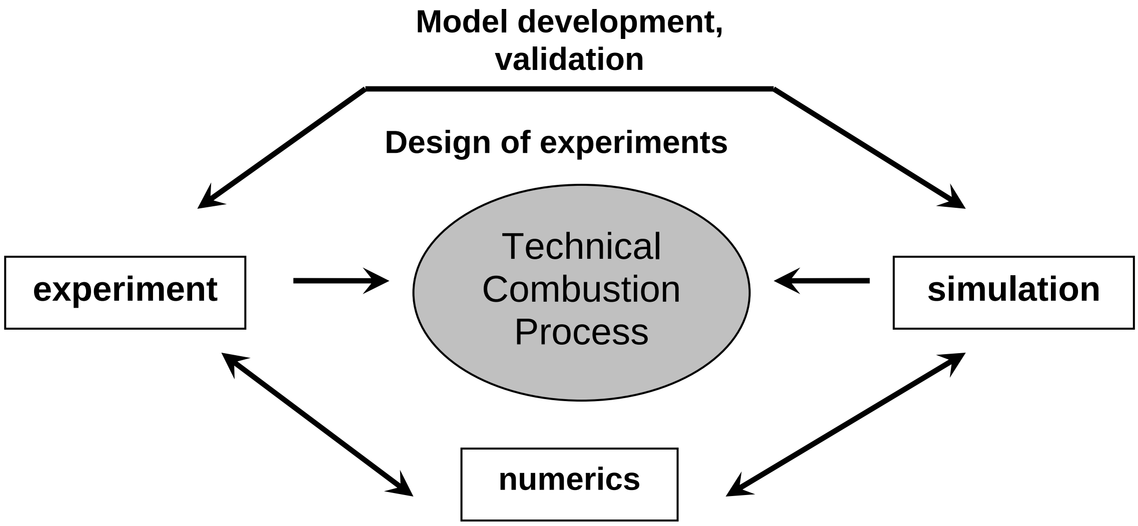

Figure 1.1
Mutual interconnections between experiments, numerical simulations/modelling and numerical recipes to improve current combustion technology.

For an experimental investigation of a combustion process two ingredients are necessary: 1) a test rig where the combustion process of interest can be operated and 2) suitable methods for its experimental characterisation. Both aspects will be discussed here to some extent but the discussion is restricted only to **generic, gaseous and continuous combustion processes** that feature some characteristics of general interest and to **laser-optical measuring techniques**. Topics such as coal or spray combustion are apparently excluded here.

Optical- and especially laser-based methods are commonly used to study combustion processes in detail. This is attributed to the following features: 1) Optical methods are non- or minimal invasive. 2) Optical techniques can be applied in-situ. The only prerequisite is a suitable optical access. 3) The temporal resolution in comparison to probe-sampling-techniques