Engler-Bunte-Institut - Verbrennungstechnik
Simulation reaktiver Thermo-Fluid Systeme (EBI-TFS)
Engler-Bunte-Ring 7
76131 Karlsruhe
vbt.ebi.kit.edu

Bachelor or Master Thesis

Numerical investigation of laminar CH_4/H_2 co-flow diffusion flames

Motivation

Given that the combustion of hydrocarbon fuels (e.g. CH_4 which is the main component of natural gas) accelerates climate change, the study of alternative fuels, e.g. H_2, is a high-impact area of research. The existing gas-infrastructure is not yet capable of handling 100% H_2 such that CH_4/H_2-mixtures are a promising alternative for the reduction of carbon emissions. The thermophysical properties of H_2 and CH_4 are very different, thus, the fundamental combustion behavior of CH_4/H_2–mixtures needs to be studied for safety aspects, combustion efficiency and NO_x emissions. Studying turbulent flames is complex due to a superposition of turbulence with various effects, e.g. preferential diffusion of hydrogen and flame lift-off. Hence, to reduce complexity, the present study will restrict itself to laminar flow conditions.

Project description

This project aims for a detailed understanding of laminar CH_4/H_2 co-flow diffusion flames with computational fluid dynamics (CFD). While experiments capture various flame quantities, e.g. flame structure and soot formation, there are certain effects in flames with high hydrogen content that are not fully understood and hard to access experimentally, e.g. differential diffusion of atomic hydrogen or detailed chemical effects. However, in CFD full velocity, temperature and species fields are predicted and allow for a deeper analysis. Figure 1 (left) shows a sketch of the experimental setup, while Fig. 1 (right) shows camera images of the laminar flames series with increasing hydrogen content from left to right. The experimental campaign demonstrates that the flame characteristics change substantially with increasing hydrogen content, with pure CH_4 flames producing soot, while pure hydrogen flames exhibit no soot formation and display broader structures. The aim of the present project is to explore and explain the observed transition.

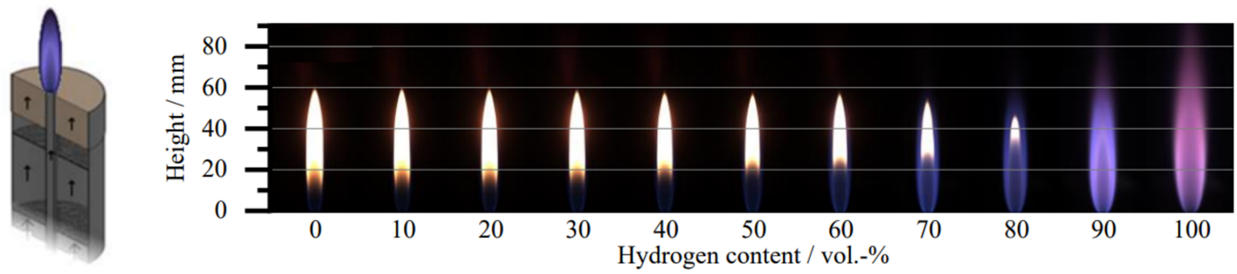

Figure 1: A sketch of the experimental co-flow burner design (left). Resulting flames with increasing hydrogen content captured in the experiments (right).

Tasks

- Review the literature to gain knowledge on reactive flows, specifically laminar flames of CH_4/H_2-mixtures
- Familiarize with the basics of numerical methods, computational fluid dynamics and OpenFOAM
- Adjust an existing case based on the experimental setup and carry out simulations corresponding to the flame series under investigation
- Extend the model to account for differential diffusion
- Time-permitting: Extend the model to account for soot formation
- Present, evaluate and interpret the simulation results
- Write a BSc/MSc thesis and present the project

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Learning objectives

- Learn the application of the computational fluid dynamics software OpenFOAM (CFD)
- Solve complex engineering problems independently
- Understand the methodology and modeling of reactive flows
- Develop code and models in the programming language C/C++

Background knowledge

Students of chemical engineering/process engineering (or similar) interested in numerical work. Previous knowledge on numerical flow simulation, fluid mechanics and programming (e.g. C/C++, Python, Matlab or similar) are helpful background information, but not strictly required.

Date, Location

Immediately, CS

Contact

If you are interested, feel free to contact us:

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