University of Bremen

CENTER OF APPLIED SPACE TECHNOLOGY AND MICROGRAVITY

ZARM

Numerical Modeling of Droplet Evaporation and Combustion

BACKGROUND

Liquid spray combustion occurs in many combustion systems, such as rocket engines, gas turbines and internal combustion engines. This process involves multiple nonlinear, strongly coupled sub-process, including atomization, evaporation, ignition and combustion, as well as droplet-droplet interactions within the spray. The complexity of the system makes its characterization challenging, and its numerical resolution exceeds the capabilities of current computational resources. One common strategy for investigating these processes is to simplify the system as much as possible, while preserving the main physical mechanisms. In this context, the study of single droplets, the most fundamental part of a spray, represents a reasonable compromise between model simplicity and maintaining the key physical processes. A deeper understanding and more accurate characterization of single droplet evaporation and combustion can contribute to improved efficiency, enhanced operational safety, and reduced pollutant emissions in combustion systems.

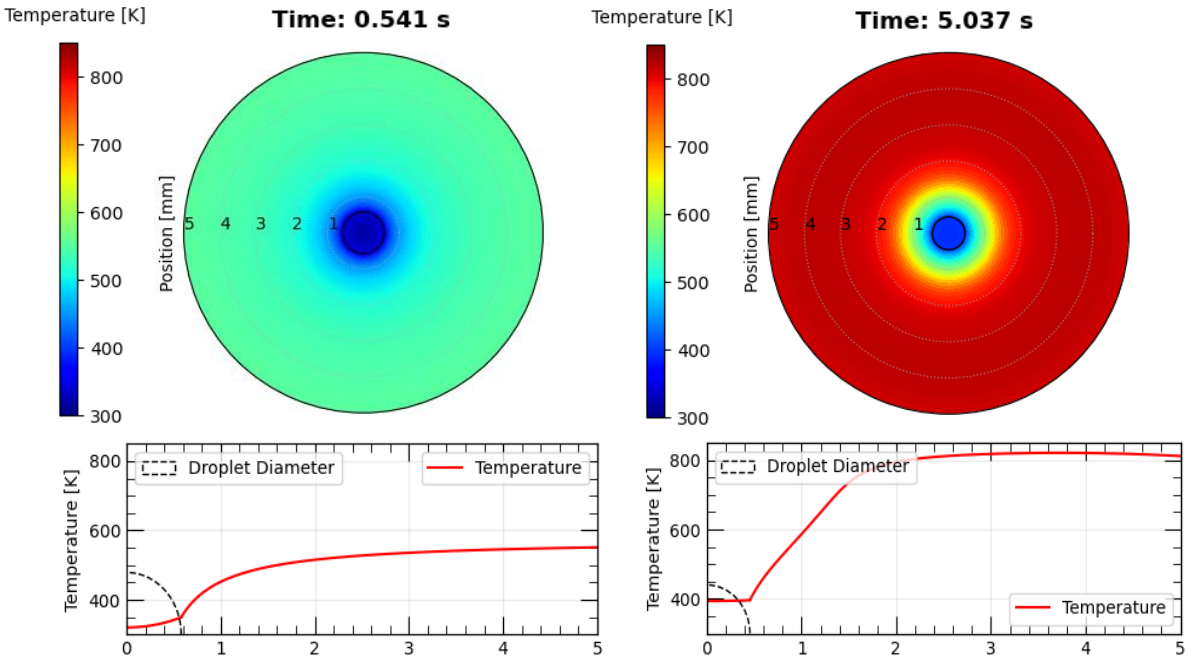

Fig.: Evolution of the temperature field obtained using a 1D numerical model.

The combustion group at ZARM has extensive experience in conducting droplet experiments under microgravity conditions at the Bremen Drop Tower. The use of microgravity is essential in fuel droplet studies, as it simplifies the governing physics and allows a more direct comparison between experimental data and numerical simulations. In parallel, detailed numerical models of these systems have been developed and validated against experimental data. Current efforts are focused on refining these models and extending their capabilities to achieve a better agreement with experimental observations. Numerical simulations complement the experiments by providing deeper insight into the results, enabling a better interpretation of the observed phenomena. The resulting findings can then be extended to more complex combustion models.

MAIN GOAL

The goal of this project is to develop a two-dimensional (2D) simulation environment using the open-source software Basilisk, while gaining practical experience with the software. The available online documentation and code will be used to adapt a numerical setup capable of simulating the evaporation and combustion of individual fuel droplets. This setup will allow the analysis of how different parameters, such as pressure, temperature or fuel type, influence the combustion characteristics. The 2D model will be compared with the detailed one-dimensional (1D) models currently developed and used by the ZARM combustion group. In addition, the model will be validated against published experimental data and recent experimental results.

SPECIFIC TASKS

(for Bachelor's thesis)

- Install Basilisk and perform some general tests.
- Model a droplet evaporation case.
- Perform simulations under different conditions and compare with detailed 1D simulation results, data available in the literature and experimental measurements.

(for Master's thesis)

- Investigate detailed and reduced kinetic mechanisms reported in the literature.
- Implement a simplified mechanism in the developed droplet evaporation framework and perform droplet combustion simulations under different environmental conditions.
- Compare results with detailed 1D simulation results, as well as with experimental measurements and data reported in the literature.
- Evaluate the feasibility of simulations using more complex kinetic mechanisms, identify model limitations, and define future work.

REQUIREMENTS

- Programming skills, e.g. Python, MATLAB, C++, etc.
- Prior knowledge in at least two of the following areas: combustion, thermodynamics, fluid dynamics, numerical methods, physics, chemistry.
- Very good written and spoken English skills.

CONTACT

➢ Noelia Martínez Figueira (noelia.martinez.figueira@zarm.uni-bremen.de)