Hessisches Kompetenzzentrum für Hochleistungsrechnen

Unsteady Modelling and Simulation of Solid Fuel Combustion in Oxyfuel Atmospheres

Project Manager
Pascal Steffens

Researchers
Leon Loni Berkel

Principal Investigator
Prof. Dr.-Ing. Christian Hasse

Project Term
2022 - 2023

Clusters
Lichtenberg II Cluster Darmstadt

Software
OpenFOAM

Additional Software
Cantera

Institute
Simulation of Reactive Thermo-Fluid Systems

University
Technische Universität Darmstadt

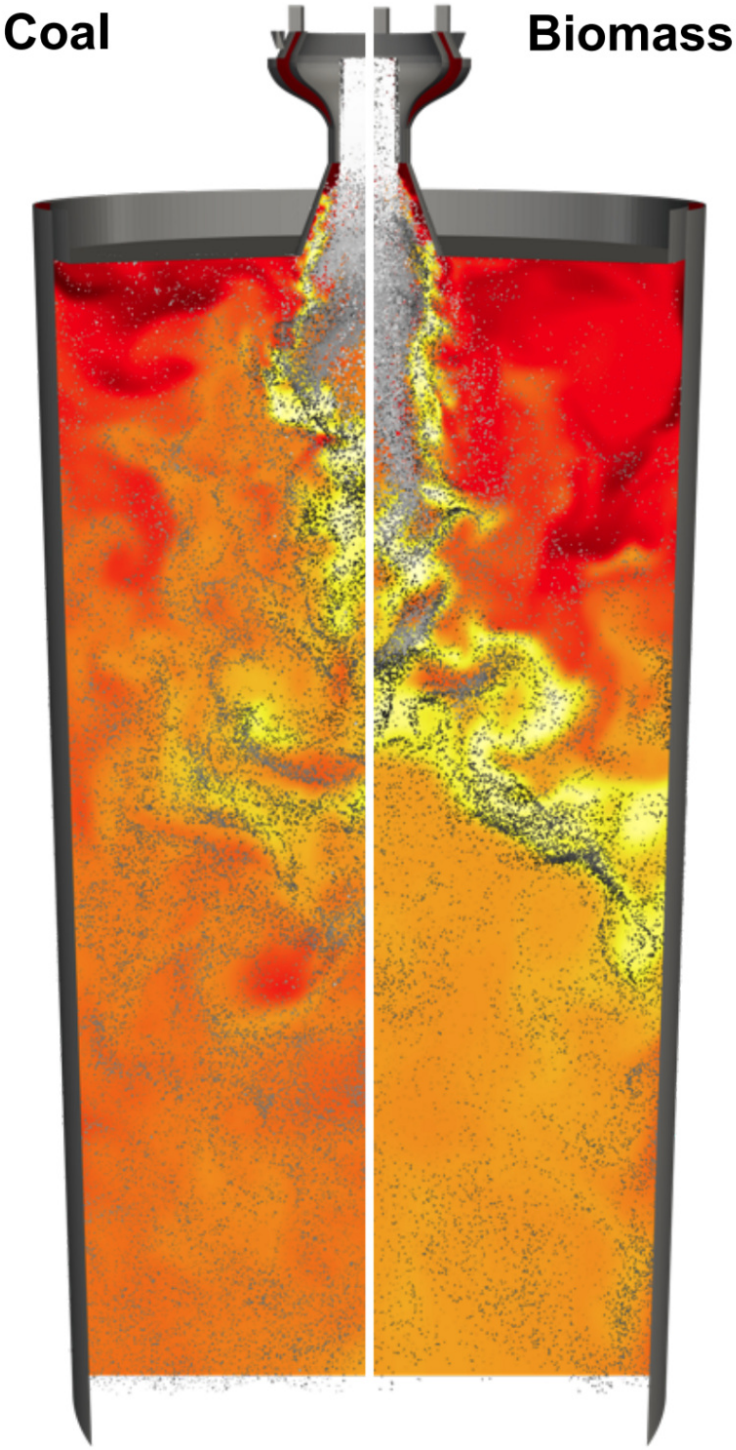

Figure 1: Temperature field and particles of coal (left) and biomass (right).

Introduction

The advancing climate crisis requires the rapid reduction of CO2 emissions. One of the largest emitters is the energy sector, which still largely depends on fossil fuels like coal, natural gas, and oil. Coal, in particular, has a very high climate impact due to its high emissions per kWh, while at the same time being very common in Germany and around the world. Retrofitting existing coal power plants to run on pulverized biomass is a viable option to reduce CO2 emission without relinquishing a controllable source of power generation. Therefore, this project aims to unravel the differences between coal and biomass combustion in a semi-industrial research burner using computational fluid dynamics (CFD) to facilitate modification of existing coal power stations. This project is a part of the Collaborative Research Center (CRC) 129 Oxyflame.

Methods

The simulation of solid fuel combustion is still quite challenging. A wide range of physics have to be taken into account to achieve accurate results. On the one hand, the particle movement, heating, devolatilization (release of volatile components), and char combustion have to be computed. On the other hand, gas phase fluid dynamics, combustion, and radiation require appropriate treatment. In the present case, these physical phenomena are simulated using a substantially adapted version of the opensource simulation library OpenFOAM. The particle model has been extended to more accurate models. Turbulence is simulated using a Large Eddy Simulation (LES) and the complex computation of the chemical kinetics is performed using a tabulated chemistry approach that has been enhanced for the combustion of solid fuels. In the framework of the CRC 129, different burners with varying complexity are investigated. The present configuration is at an intermediate scale between industrial- and laboratory-scale burners, shares similarities with industrial burners, and allows solid fuel combustion without the assistance of methane. To thoroughly compare the combustion of coal and biomass, the inflow velocities and thermal power were kept same for both fuels.

Results

The simulations demonstrated the feasibility of LES and tabulated chemistry for the combustion of biomass. The results of particle velocities for coal and biomass were validated with measurements from our experimental partners and showed good agreement. The simulations showed that coal and biomass flames look different, even though they both produced anchored flames. The biomass flame was significantly longer.

Discussion

The changed flame shape visible in the simulation results could be attributed to the particle size. Typically, biomass particles can be ground less finely due to their fast release of combustible volatiles. In the present simulation, this resulted in slower heatup and release of volatiles at a different position in the flame leading to the change in flame shape. Such results are important for the retrofitting of existing coal power plants and to decarbonize the energy economy.

Publications

Pascal Steffens, Large Eddy Simulation of Self-Sustained Solid Fuel Combustion, Presentation 4th International Workshop on Oxy-Fuel Combustion, Naples, Italy, March 22-23, 2023

Leon Loni Berkel, Comprehensive Analysis of the Effect of Oxyfuel Atmospheres on Solid Fuel Combustion Using LES, Poster at 4th International Workshop on Oxy-Fuel Combustion, Naples, Italy, March 22-23, 2023

Pascal Steffens, Coal vs Biomass: LES of 40 kW Dust Flames, Poster at 31. Deutscher Flammentag 2023, Berlin, Germany, September 27-28, 2023

Last Update: 2023-12-07 16:22