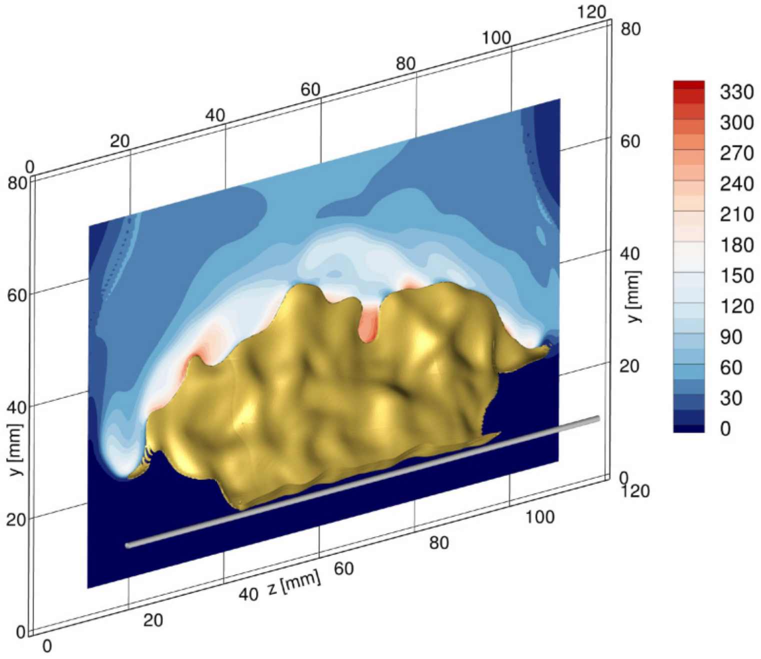
Investigations of the Flame Dynamics of a Side Wall Quenching Flame



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Heat Energy Technology, Thermal Machines, Fluid Mechanics

Clusters
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Software
FASTEST

Institute
Institute for Energy and Power Plant Technology

University
Technische Universität Darmstadt

Introduction

Since nearly 86% of the world wide energy demand is obtained through combustion, it is necessary to improve related processes. In this project we focused on the interaction of flames with cold walls, especially premixed methane. This interaction is still not completely understood. For complex geometries it is not feasible to resolve all flow scales and solve all chemistry reactions. Due to that, we used highly resolved Large Eddy Simulations (LES), by which nearly all flow scales could be captured and the modeling part was minimal. The combustion was treated with a tabulated chemistry approach called Flamelet Generated Manifold (FGM), which is a good compromise between computational costs and accuracy.

Methods

For this purpose we conducted 2D and 3D simulations for laminar and turbulent conditions and compared the results with experimental data and detailed chemistry (DC) simulations. In the configuration considered in this work, only the flame tip touches the wall and gets quenched. This is called sidewall quenching (SWQ) and can be seen exemplarily for the 3D laminar configuration in Fig. 1. As explained in the resulting publication [1] only 3D simulations can captured all flow and flame characteristics at the same time. Nevertheless, the 2D simulation were used to understand the influence of modeling parameters. The three dimensional simulations had 22 million control volumes and each needed more than 250,000 CPUh. This kind of resources can only be provided from high-performance computer.

Results

The laminar simulations, which are in good agreement with the experimental results, determined the limits of the modeling approaches used and explained the differences to the experiments concerning the concentration of minor species. With this knowledge the turbulent cases could be conducted [2]. As can be seen in Fig. 2 the flame front shape and wall heat fluxes are strongly influenced by the turbulent flow. The turbulent results also showed good agreement with the experimental data. Based on that, further analyses were made. The relations between heat fluxes and quenching distances for the laminar case differ from the turbulent. Additionally, the turbulent flame tip behaves temporally like a head-on quenching flames, that means it is nearly parallel to the wall and quenches on a larger region. In this context the movement of the flame tip in the vicinity of the wall was evaluated and three different movements of the flame tip could be identified and partially explained [3]. To determine the influence of the models used, a finer grid should be used. This could improve the simulation twofold. First the flame does not need to thickened anymore and second the turbulent scales could be completely resolved and no LES-modeling would be necessary.

Figures

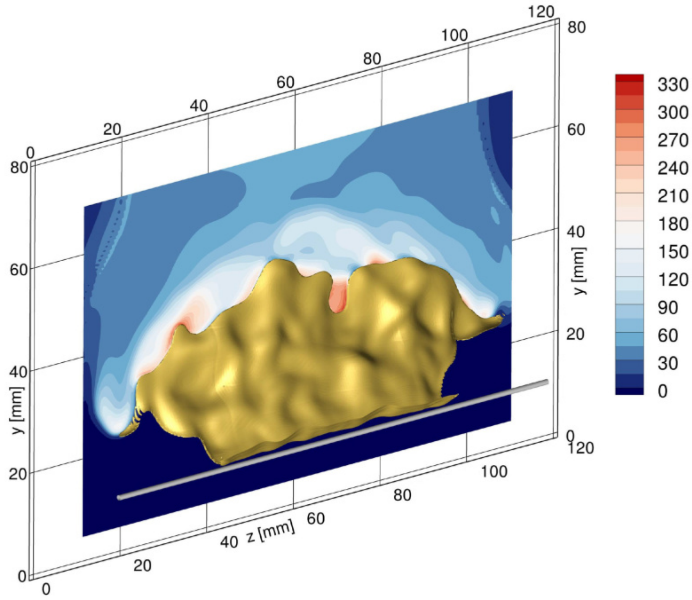

Figure 2: Snapshot of the wall heat flux for turbulent 3D reacting simulation with FASTEST. The orange iso-surface shows the position of the flame front and the gray iso-surface represents the rod.

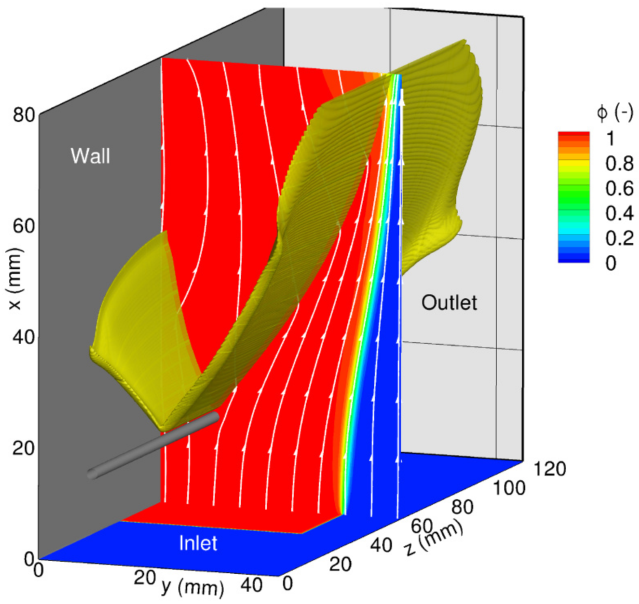

Figure 1: Domain of the 3D laminar sidewall quenching simulation colored with equivalence ratio and overlayed with streamlines (white lines). The flame front (yellow iso-surface) and the rod (gray iso-surface) are shown.

Reference

[1] Heinrich, A.; Ganter, S.; Kuenne, G.; Jainski, C.; Dreizler, A.; and Janicka, J.: 3D Numerical Simulation of a Laminar Experimental SWQ Burner with Tabulated Chemistry. Flow, Turbulence and Combustion, Vol. 100, Issue 2, (2017) https://doi.org/10.1007/s10494-017-9851-9

[2] Heinrich, A.; Ries, F.; Kuenne, G.; Ganter, S.; Hasse, C.; Sadiki, A.; and Janicka, J.: Large eddy simulation with tabulated chemistry of an experimental sidewall quenching burner. International Journal of Heat and Fluid Flow, Vol. 71, (2018) https://doi.org/10.1016/j.ijheatfluidflow.2018.03.011

[3] Heinrich, A.; Kuenne, G.; Ganter, S.; Hasse, C. and Janicka, J.: Investigation of the Turbulent Near Wall Flame Behavior for a Sidewall Quenching Burner by Means of a Large Eddy Simulation and Tabulated Chemistry. Fluids, Vol. 3, (2018). https://doi.org/10.1016/j.ijheatfluidflow.2018.03.011

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