

# Combustion in swirling flows, modelling of premixed turbulent combustion in swirling flows using large eddy simulations and tabulated chemistry

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*'Combustion in Swirling Flows, Modelling of Premixed Turbulent Combustion in Swirling Flows using Large Eddy Simulations and Tabulated Chemistry'*

Technische Universiteit Eindhoven, (2015)

## Abstract

Modern industrial burners often operate under lean (sub-stoichiometric) conditions. This reduces the production of harmful pollutants, but decreases the stability of combustion. Flame stabilization is achieved by introducing a swirling motion to the flow. This motion creates a recirculation zone that transports heat and active chemical species back to the flame front. However, predicting the stability and behaviour of these flames is not straight-forward. The swirling flow-flame interaction is very complex and the flow is often highly turbulent. Modelling this phenomenon can be achieved by running a Large Eddy Simulation (LES), an unsteady numerical technique in which the large turbulent flow structures are resolved and smaller ones are modelled.

In this work, the problem of modelling a turbulent swirling reacting flow is tackled by first separating the problem into two test cases; one for the turbulent swirling flow and the other of the combustion chemistry. In the first case, a cold turbulent swirling flow has been modelled with time-dependent LES using the open source CFD package OpenFOAM®. Based on comparisons to experimental data, the LES results accurately predicted velocity profiles as well as key flow features, such as the recirculation zone and the Precessing Vortex Core (PVC).

For the second case a Direct Numerical Simulation (DNS) of a laminar premixed lean methane/air flame has been computed using the Flamelet-Generated Manifold (FGM) technique [1]. This technique solves the chemistry solution offline and stores it in a table to be used during the simulation. The implementation into the CFD has been achieved using Tabkin© by Dacolt [2]. The effectiveness of FGM is demonstrated by comparing the results of the laminar flame to detailed chemistry solutions. The results are nearly identical, with the FGM result being computed almost 7 times faster. Such a speedup is crucial when attempting to model larger practical flames.

Finally, a numerical study is conducted on the Cambridge-Sandia Swirl Burner [3] using the 'best-practice' methods from the two cases above. The results of this simulation campaign have been presented on the poster. Without tuning model parameters and within reasonable computational effort, the model is able to correctly predict both the swirling flow and important flame characteristics, such as the flame angle. Also, as a large part of the turbulence is resolved by the LES approach, both average values as well as fluctuations in velocity, temperature and equivalence ratio are accurately predicted. The results of this simulation campaign showcases the potential of the model for further developments in gas turbine combustors.

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