Turbulent Premixed Combustion with FGM in COMSOL Multiphysics®

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Introduction: Solving complex chemistry as in turbulent premixed combustion is hard to do, there are many species and time-scales making problems stiff and memory intesive. We use the correlation of species in a representative flamelet to lookup the source term. This is called flamelet generated manifolds (FGM, [1]. Here it is introduced in Comsol to model a reactive turbulent backward facing step (El Banhawy et al. [2]).

Computational Methods: In this simulation we first solved the turbulent flow with steady k-ε equations. Here the inflow Reynolds number was 10,000 and the mean inflow velocity was 9 m/s. In the next step we solved an unsteady transport equation for the flame **progress variable, *c***. With a detailed chemistry code the source term of this progress variable was tabulated. This **source term** was used to continue the integration. In the turbulent case it was convoluted by a β-PDF to include the role of the variance of *c*, that was modelled as an algebraic model. The *c* is taken as CO_2.

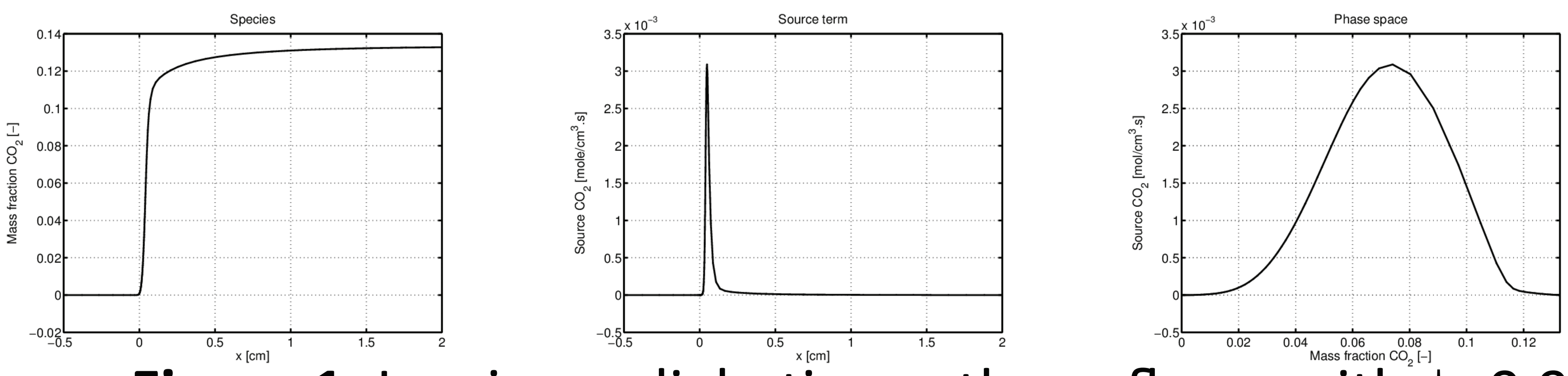

Figure 1. Laminar adiabatic methane flame with ϕ=0,9 species 2 source term, 3 phase space

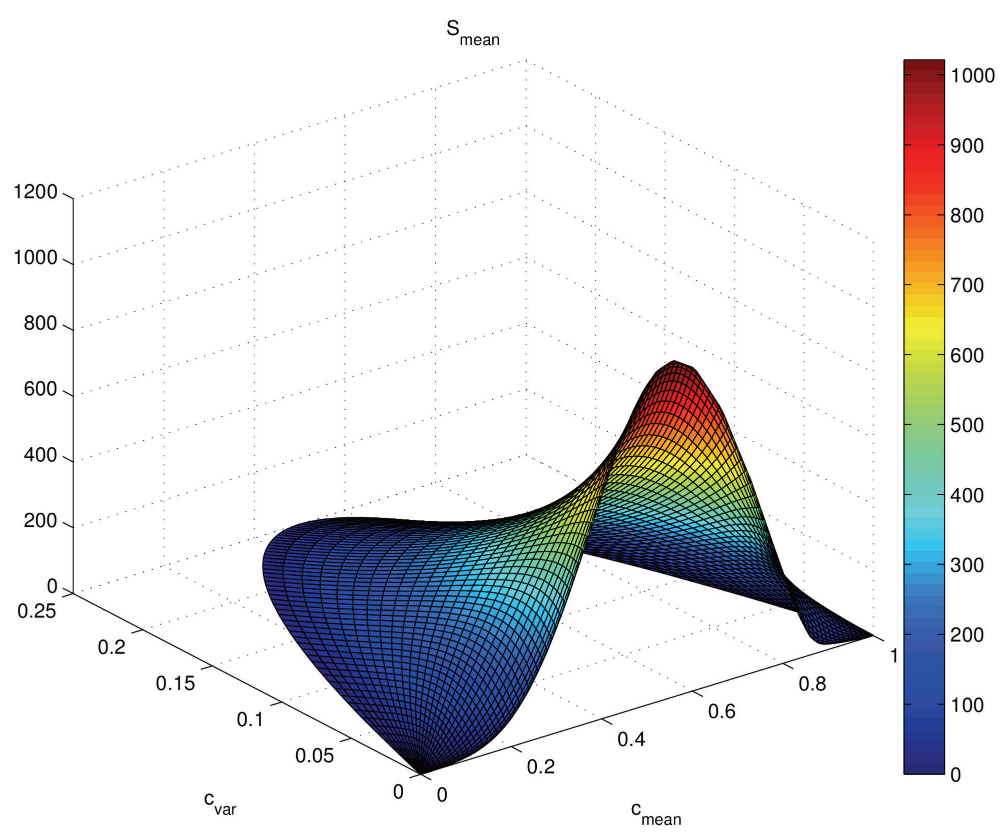

Figure 2. Turbulent manifold, Step 3 convoluted with a β-pdf

Cold flow results: In figure 3 the backward facing step flow is presented. The recirculation length is in agreement with literature.

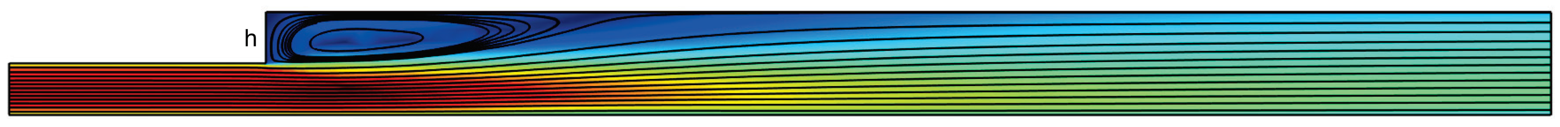

Figure 3. Backward facing step flow with Re=10,000, the recirculation length is l=6.65h

Reactive flow results: A turbulent flame brush is added at the expansion and then a time integration of 0.1 s is performed. This results in a quasi steady flame result, see figure 4 for *c*.

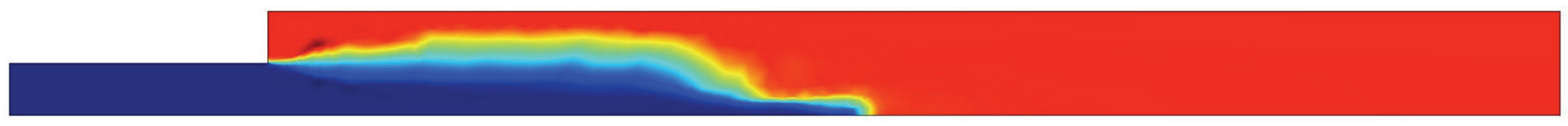

Figure 4. Mean progress variable c at 0.1 s after initiating at the expansion.

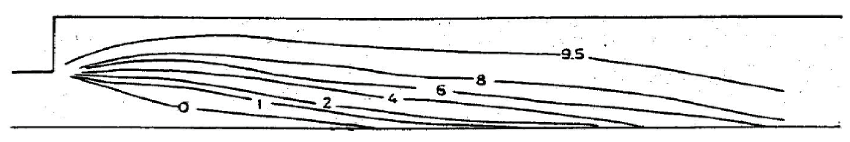

Figure 5. Mean value of CO_2 as reported by Al Banhawi et al.

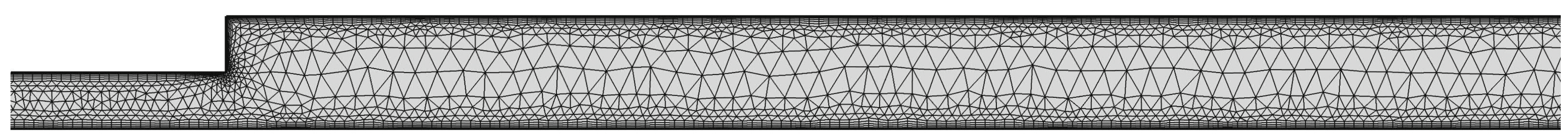

Figure 6. Mesh of the calculation.

Future improvements:

- Include expansion
- Include heat loss
- Expand to 3D
- Application of LES

Conclusions: From the present approach and the resulting solutions it can be concluded that the combination of the Comsol flow solver with the FGM method for describing combustion is a good method to calculate reacting flows. Sufficient resolution is required to keep the the *c* within bounds.

References:

1. J.A. van Oijen & L.P.H. de Goey, Modelling of premixed laminar flames using flamelet-generated manifolds. Comb. Sci. Technol. 161, 113--137, (2000).
2. Y. Al Banhawy, S. Sivasegaram & J.H. Whitelaw, Premixed, Turbulent Combustion of a Sudden Expansion Flow. Comb. & Flame, 50, 153-165, (1983).