Turbulent Premixed Combustion with FGM in COMSOL Multiphysics®

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Abstract

Introduction
In reacting flows, and especially in combustion, the problem is always attached to the representation of the chemistry. In general there are many reactions between lots of species. The current consensus on what is a good kinetic scheme involves 53 species and 325 reactions for simple methane combustion. Besides the fact that transport equations have to be solved for many species, also short time scales are involved making the problem stiff. At Eindhoven University we developed the method of Flamelet Generated Manifolds (FGM). It can be used for laminar and turbulent combustion and premixed and non-premixed situations.

Up till now FGM has been used in RANS, LES and DNS codes. Often the first two were involved with large commercial finite volume codes and the second two mainly in research codes. Here we present the use of the method in combination with COMSOL Multiphysics®. We will consider a turbulent case, being a burning backward facing step flow. This was investigated in a physical experiment published by El Banhawy et al..

Use of COMSOL Multiphysics®
The backward facing step was operated burning methane at an equivalence ratio of 0.9. For this we defined 3 studies in a simulation. The first two were dedicated to solve the turbulent stationary cold flow with the k-ε model. The Reynolds number was 10,000 and the mean flow was 10 m/s. We did this in an incompressible mode. A good value of the recirculation length was obtained. In the 3rd step we solve an unsteady transport equation for the time or ensemble average progress variable and its variance. A flame brush is initialized with a hyperbolic tangent profile centered at the step location.

Turbulence is represented by the variance of the progress variable with a gradient model. With the progress variable and its variance a manifold is approached to look up the source term of the progress variable, necessary to advance this equation in time. The manifold is pre-computed with the dedicated 1D chemistry code CHEM1D. A laminar flamelet at the correct equivalence ratio is taken and convoluted with a beta-PDF chance distribution.

Results
In Figure 1 a result is given of the reacting backward facing step flow. The domain length is 0.5m. At the given time the simulation shows a more or less stationary flame front. At the top

small fluctuations take place.

Conclusion

From the present approach and the resulting solutions it can be concluded that the combination of the COMSOL Multiphysics® flow solver with the FGM method for describing combustion is a good method to calculate reacting flows, presently for laminar and turbulent premixed flames. There seems to be no limitation to also do simulations for non-premixed cases where an equation of the so called mixture fraction has to be solved. Sufficient resolution or grid refinement needs to be used to keep the progress variable within its physical bounds.

Reference

Y. El. Banhawi et al., Premixed, Turbulent Combustion of a Sudden-Expansion Flow, Combustion and Flame, 50, 153-165, 1983

Figures used in the abstract

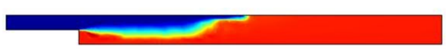

Figure 1: Spatial distribution at t=0.1 sec., of the progress variable, which is the scaled amount of CO_2, blue: fresh mixture, red: burnt