Investigating Detailed Chemistry Bunsen Flames with Adaptive Finite Element Methods

E. Burman[1], A. Ern[2], and V. Giovangigli[3]

Abstract: The investigation of axisymmetric, laminar Bunsen flames is extremely valuable in improving our understanding of many complex combustion phenomena such as pollutant formation, ignition processes and chemically controlled extinction limits. Although most practical combustion systems involve three-dimensional, turbulent flames, accurate models of axisymmetric, laminar flames can aid significantly in designing turbulent combustion models. Laminar flames with advanced chemical mechanisms still pose highly challenging difficulties for their numerical simulation.

The equations governing Bunsen flames express the conservation of chemical species mass, momentum and energy in the low Mach number limit. We consider a finite rate chemical mechanism for H_2/Air combustion involving 9 chemical species participating in 19 elementary reactions. We also account for detailed multicomponent transport, including multicomponent molecular diffusion, thermal diffusion and kinetic theory expressions for the thermal conductivity and the shear viscosity of the mixture.

The governing equations are discretized using stabilized, linear finite elements on conforming, fully unstructured triangulations. The stabilization involves least squares control of streamline derivatives and pressure-velocity couplings as well as nonlinear, crosswind, schock-capturing terms yielding additional stability in the vicinity of flame fronts. A posteriori error estimates derived using the dual weighted residual method are used to refine the mesh adaptively. The meshes generated in the adaptive process are unstructured, Delaunay-type triangulations. Numerical results will be presented in order to assess the impact of specific target error functionals on mesh refinement and also to investigate the hydrodynamic stability of Bunsen flames for various flow configurations.

[1] Département de Mathématiques, EPFL
MA-Ecublens, CH-1015 Lausanne, Switzerland
erik.burman@epfl.ch

[2] CERMICS, Ecole nationale des ponts et chaussées
6 et 8, avenue Blaise Pascal, F-77455 Marne la Vallée cedex 2, France
ern@cermics.enpc.fr

[3] CMAP, Ecole polytechnique et CNRS
91128 Palaiseau cedex, France
giovangi@cmapx.polytechnique.fr