MULTI-SCALE ASYMPTOTIC ANALYSIS OF A LAMINAR PREMIXED FLAME

S. Bomberg*[13], J. Zips[1], W. Polifke[1], R.I. Sujith[23]

[1] Lehrstuhl für Thermodynamik, Technische Universität München
Boltzmannstraße 15, 85747 Garching, Germany
[2] Dept. of Aerospace Engineering, Indian Institute of Technology Madras
Chennai 600036, India
[3] Institute for Advanced Study, Technische Universität München
Lichtenbergstraße 2a, 85747 Garching, Germany
* Corresponding author: bomberg@td.mw.tum.de

Due to low Mach numbers (Ma), thermoacoustics are often solved in a 'divide and conquer' fashion. However, the widely used decomposition into steady mean and small fluctuations is not attributed to the vanishing Ma and terms of different order co-exist. Thus, invoking a zero base flow assumption without dropping velocity fluctuations u' is mathematically inconsistent. Generally, flow/acoustics-coupling cannot be described properly and the single input/single output flame model structure (SISO) is an ad hoc assumption.

Low Mach number flow is identified as a singular perturbation problem. Application of the Method of Multiple Scales to a compact flame (single time/disparate spatial scales) yields two coupled sets of equations for the different scales. The combustion process not only reacts to u' but is also affected by the acoustic pressure gradient through baroclinic torque. Vice versa, combustion acts as a source of acoustic mass, momentum and energy. Consequently, an appropriate flame model should comprise multiple inputs and outputs (MIMO). The present work assesses the different coupling mechanisms by comparison with a brute force DNS of a laminar premixed flame.

References

[1] J. Kevorkian and J. D. Cole. *Multiple Scale and Singular Perturbation Methods*. Springer-Verlag New York, Inc., New York, New York, USA, 1996.

[2] R. Klein. Multiple Spatial Scales in Engineering and Atmospheric Low Mach Number Flows. *ESAIM: Mathematical Modelling and Numerical Analysis*, 39:537–559, 2005.

[3] R. Klein, N. Botta, T. Schneider, C. D. Munz, S. Roller, A. Meister, L. Hoffmann, and T. Sonar. Asymptotic Adaptive Methods for Multi-Scale Problems in Fluid Mechanics. *Journal of engineering Mathematics*, 39:261–343, 2001.

[4] A. Meister. Asymptotic Single and Multiple Scale Expansions in the Low Mach Number Limit. *SIAM Journal on Applied Mathematics*, 60(1):256–271, 1999.

[5] M. Van Dyke. *Perturbation Methods in Fluid Mechanics*. The Parabolic Press, Stanford, California, USA, annotated edition edition, 1975.