



Turbulence-Chemistry Interaction in Ethylene/Air Compressible Reacting Shear Layers

Helm CM^{1*}, Peterson DM²

*lead presenter: clara.helm.ctr@us.af.mil

1 Innovative Scientific Solutions Inc., Dayton OH-45459, USA

2 Air Force Research Laboratory, Wright-Patterson AFB, OH-45433, USA

The internal flow field of any high-speed combustion engine is typified by a highly complex non-linear coupling between chemical kinetics, turbulence, and compressibility [1]. The current practice for the simulation of high-speed combustors is to apply the models derived for the incompressible regime to the compressible regime with no modifications. There is, however, much evidence that the nature of the turbulence-chemistry interactions changes significantly from incompressible to compressible conditions, potentially rendering these models entirely inaccurate in this regime. One common assumption for model derivation is the classic turbulence energy cascade which describes turbulent kinetic energy (TKE) as being generated at large scales, transferred inviscidly to smaller and smaller scales, and finally dissipated into the smallest viscous scales. However, studies show that a reverse energy transfer can occur in the vicinity of the flame front [2] and that the behavior of this “backscatter effect” is further altered by compressibility [3]. Likewise, observations of distributed reaction zones in highly compressible turbulent flames [1] brings into question the validity of the classic assumption of the separation of chemical and turbulence scales and the modeling of the turbulent flame as laminar “flamelets”. Additionally, it has been observed that, in high-speed reacting turbulence, the vortex generation by both dilatation and baroclinic torque can be on the same order as the vortex stretching [4]. Understanding the fundamental physics involved in these phenomena is crucial to identifying the important requirements for compressible model closure techniques.

Toward this end, the current work is an investigation into the mechanisms of turbulence-chemistry interactions in a set of DNS simulations of ethylene-air compressible mixing layers that covers a range of convective Mach numbers up to 2.5 and includes both premixed and non-premixed conditions. Specifically, we will report the effect of convective Mach number on the statistics of TKE backscatter, flame surface topology, flame-normal profiles, and vorticity generation by baroclinic torque and dilatational mechanisms. Results will provide information on the potential shortcomings of classical modeling assumptions for the Large Eddy Simulation in this regime. This study builds off the work of reference [5].

References

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