Ph.D. Thesis Defense
by
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“Turbulence Effects on Chemical Pathways for Lean Premixed Flames”

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Abstract:
Turbulent combustion, particularly premixed combustion has great practical importance due to their extensive industrial usage in gas turbines, internal combustion engines etc. However, the physics governing the inherent multi-scale interactions of turbulence, flow-field and chemistry is not yet well established. A complete understanding of each of these interactions and their coupling is essential for the development of models that can aid simulations of realistic engines (using Large Eddy Simulations (LES) or Reynolds averaged Navier-Stokes equations (RANS). Particularly, understanding the flame structure and its stabilization requires an understanding of the turbulence-chemistry interactions. This can manifest itself in many different forms. For example, flame wrinkling gives rise to flame stretch that can modify the local temperature and species concentrations in turn altering the local chemistry. Also, the smaller eddies in a turbulent flow can penetrate into the preheat and reaction zones changing the species’ gradients within the flame.

In this work, the effect of increasing turbulence on chemical pathways for fuel oxidation is investigated using Direct Numerical Simulations (DNS) for three different fuels: hydrogen, methane and n-dodecane. A “global” analysis using different metrics is performed to quantify their changes averaged over the entire and using multiple data conditioners such as fuel consumption, curvature etc. The results are also compared and contrasted with simple laminar flame models such as unstretched flames, stretched flames and perfectly stirred reactors. Conditional means of reaction rates are calculated to identify characterize a “local” influence of turbulence on chemistry. These conditional means are also compared to laminar flames and regions of good agreement and deviation are identified. Finally, transport models representative of the changes due to turbulence are developed to identify the underlying physics leading to the changes in the chemical pathways for these lean premixed flames.

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