



Analysis of Turbulence Premixed Hydrogen/Air Combustion in a Bluff-Body Burner for Gas Turbine applications

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The increasing concern over global warming and the role of human activities in accelerating this phenomenon has drawn significant attention to the adoption of carbon-free fuels, such as hydrogen, especially in hard-to-electrify industrial sectors. However, the use of hydrogen in technical applications has been limited due to several inherent challenges. In particular, hydrogen combustion is highly complex due to non-unity Lewis number effects, which result in flames with higher propagation speeds, potentially leading to hazardous phenomena such as flashbacks. To ensure the safe and efficient use of hydrogen in industrial applications, it is crucial to develop accurate models and physical understanding of hydrogen-air combustion under practically relevant conditions. The flame consumption speed, one of the main quantities determining the flame behavior, is strongly affected by the turbulence and non-unity Lewis number effects and their interaction. The extent to which these two phenomena enhance this value depends critically on the thermophysical properties of the system, specifically, the Zeldovich number (Ze , dimensionless global activation energy), the Peclet number (Pe , the ratio of convective to diffusive fluxes), and the Lewis number (Le , the ratio of thermal to mass diffusivity). Although the influence of these parameters, particularly the ratio Ze/Pe , has been recognized as crucial in determining the behavior of turbulent flames, a more comprehensive understanding is required under bluff-body burner conditions, which are more complicated than in a standard jet flame. This work starts by developing a database of direct numerical simulations of bluff-body stabilized hydrogen-air flames, considering the complete gas turbine burner geometry. The simulated geometry is based on the burner at the NTNU [1]. It consists of a cylindrical combustion chamber and an inlet pipe with a central conical body, which induces a recirculation zone downstream. This recirculation zone plays a crucial role in stabilizing the flame. However, due to the unique properties of hydrogen as a fuel, the interaction between the specific convective conditions and the thermodiffusive characteristics of the reacting mixture significantly influences the flame behavior. Moreover, different pressure levels are analyzed (1-3 bar), as pressure plays a crucial role in determine most of the previously discussed characteristics quantities. Statistical analysis of the simulated database are performed to describe the evolution of key flame properties (e.g., consumption speed, flame area), with the aim of gaining a deeper understanding of how these quantities are influenced by both the turbulent flow field and the thermodiffusive properties of the reacting mixture in gas turbine conditions.

References

- [1] Aguilar J G et al. The influence of hydrogen on the stability of a perfectly premixed combustor. *Combust. Flame*. 2022;245: 112323.