Mixture composition influence on schlieren images for simulated premixed H_2-air flame

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Abstract
Schlieren techniques are widely utilized for flame characterization, and ongoing research at Politecnico di Milano focuses on employing tomographic Background Oriented Schlieren (BOS) technique to measure temperature distribution in an axis-symmetric $H_2 - air$ premixed flame. The initial step in this process involves tomographic reconstruction of the refractive index distribution from the ray deflection measured from the BOS images. However, due to the unknown exact composition of the mixture, an assumption of constant composition (i.e., uniform Gladstone-Dale constant) must be made, which can significantly affect temperature accuracy.

The primary objective of this study is to analyze the dependency of refractive index and deflection on composition and how these parameters vary with changing equivalence ratios. This analysis is conducted through a 1-D planar simulation of an H_2-air laminar premixed flame. Additionally, the study aims to assess whether similar outcomes can be achieved with an axis-symmetric refractive index field simulating a Bunsen-type burner flame.

The flame simulation employs the CANTERA Python suite with the FreeSolver tool and a kinetic mechanism model for H_2 combustion. Refractive index computation in both 1D and axis-symmetric cases considers the real mixture composition, and three different scenarios assuming Gladstone-Dale constants for fresh mixture, exhaust gases, and air, applied uniformly.

For deflection estimation, a ray tracing algorithm is utilized, involving integration of a simplified form of the ray equation. Analysis of the 1D-case reveals that assuming a constant fresh mixture composition yields the most accurate results, with similar trends observed in the axis-symmetric case. Differences in results are lower for lean mixtures and increase for rich mixtures.

These findings deepen the understanding of composition's impact on deflections in Schlieren techniques and will facilitate accurate temperature estimation of the experimental H_2-air premixed flame through tomographic BOS.