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Numerical Investigation of Flame Acceleration and Overpressure Development in a Uniform and Stratified Hydrogen-air Mixture

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This study presents a numerical investigation into the flame acceleration and overpressure characteristics of a uniform and stratified hydrogen-air mixture in an open and a confined space full of obstacles. By integrating the Navier-Stokes equations into an in-house computational finite-volume solver, Morris Garages (MG-code) featuring an adaptive mesh refinement technique and burning velocities correlations, this study effectively captures the impact of mixture stratification and confinement on flame acceleration and overpressure development in a 3m-long obstacle-laden box. A turbulent burning velocity correlation spanning a range of equivalence ratio (ϕ=1-5) was implemented to impose a mixture gradient from rich to lean conditions in the box. In contrast, a stoichiometric condition was adopted for the uniform mixture. Results indicated an accelerated flame propagation and amplified peak overpressure in the rich-to-lean mixture gradient compared to the uniform mixture and were more pronounced in the confined space. The rich region, in particular, exhibited an overpressure rise exceeding one order of magnitude relative to the uniform mixture. In the open box, the inhomogeneity effect is still notable with a considerable magnitude of overpressure and flame propagation, but venting reduced the peak overpressure. This study provides a compelling insight into the role of mixture stratification on overpressure development in obstacle-laden configurations filled with hydrogen-air mixture.