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Why hydrogen flames are different:

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Abstract

The world is facing major challenges with respect to climate change and energy supply. In order to meet the energy demand for economic growth and at the same time reduce negative ecological effects, new energy conversion technologies emerge and a transition from fossil fuels to future sustainable fuels has commenced. Hydrogen is expected to play an important role in the energy mix of a future low carbon society. Current combustion applications burning natural gas, will have to be redesigned to operate on gas mixtures with large amounts of H₂ (up to 100%). The extraordinary combustion properties of H₂ make this a challenging task. The burning velocity of premixed H₂-air flames is much higher than that of methane-air flames and more sensitive to fuel-air ratio. Together with a much wider flammability range, lower minimum ignition energy, and smaller quenching distance, this may lead to serious flame stability issues and an enhanced risk of flash back. The high diffusivity of H₂ makes the physics of flame stability even more intriguing. It gives rise to preferential diffusion effects causing the formation of cellular flames in extremely lean mixtures and anomalous blow-off behaviour. In this presentation we review the physical background of these preferential diffusion phenomena and the theory that describes the effect of preferential diffusion on burning velocity and flame dynamics. The impact of these phenomena on the stabilization of laminar premixed methane-hydrogen-air flames are studied numerically and experimentally. Subsequently, we explore the modelling of such preferential diffusion effects using the flamelet-generated manifold (FGM) method. Detailed numerical simulations of premixed turbulent flames, revealing the impact of hydrogen blending on flame speed and burning rate, are then presented. Finally, several remaining challenges in the modelling of hydrogen flames are discussed.