Experimental and Numerical Investigation of Combustion Dynamics in a Diffusion Flame, Using Hydrogen and Nitrogen

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Abstract

In this research, we examined the effect of nitrogen dilution on flame dynamics and pollutant emissions in non-premixed hydrogen/air combustion in a swirl burner. This work aims to reduce the pollutant emissions of NO_x in existing gas turbines and diffusion flame burners used in boilers. Using hydrogen as a replacement for natural gas increases the flame's temperature, resulting in increased NO_x emissions. This is where nitrogen dilution comes in hand, lowering the flame's temperature and in turn, the NO_x emissions. This swirl burner was previously investigated by Ojha et al. in our group, who examined the impact of nitrogen dilution on pollutant emissions in premixed and non-premixed hydrogen/air combustion, as well as methane-hydrogen mixtures. We analyzed the flame behavior by capturing OH PLIF measurements and conducting one-dimensional numerical diffusion flame simulations. The different cases examined provided different types of turbulent diffusion flames. The case of non-diluted hydrogen produced a flame classified in the wrinkled and stretched flamelets regime, whereas nitrogen-diluted hydrogen produced a flame with a discontinuous front, somewhere along the transition between a perturbed flamelet and a thickened flame. Consequently, it is found that dilution decreased Damkohler number and increased both Reynolds and Karlovitz numbers. We can assume that turbulence was intensified by the augmented momentum generated by the added nitrogen. Vortices smaller than the reaction zone are presumably responsible for a broken flame front. Further investigation will be proposed to better validate the results. For instance, conducting premixed or partially premixed simulations, and performing particle image velocimetry (PIV) and acetone PLIF experiments, to gain a better understanding of the three-dimensional turbulent mixing process.