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Modelling Local Extinction in Turbulent Piloted $NH_3/H_2/N_2$ Jet Flames with Transported PDF and MMC Methods

Lu Tian[1,2,*] Andrew P. Wandel[3], R. Peter Lindstedt[2]
*Lead presenter: l.tian@lboro.ac.uk
[1]Department of Aeronautical and Automotive Engineering, Loughborough University, Epinal Way, Loughborough LE11 3TU, UK
[2]Department of Mechanical Engineering, Imperial College, Exhibition Road, London SW7 2AZ, UK
[3]School of Engineering, University of Southern Queensland, Toowoomba, Qld, 4350, Australia

Ammonia is a promising alternative fuel for decarbonising hard-to-abate sectors. However, its practical utilisation is hindered by unfavourable combustion characteristics, including slow chemical kinetics, low flame speeds, and high emissions of oxides of nitrogen. These challenges are further exacerbated in turbulent flames due to enhanced turbulence-chemistry interactions. This study uses the Joint-scalar transported Probability Density Function (JPDF) [1] and Multiple Mapping Conditioning (MMC) [2] frameworks, both of which inherently provide a closed treatment of the chemical source term. The methodology is applied to investigate three turbulent piloted ammonia-hydrogen-nitrogen-air flames [3] exhibiting different degrees of local extinction corresponding to 59% (Flame D), 79% (Flame E), and 89% (Flame F) of the blowoff velocity. The performance of JPDF-based models, featuring Modified Curl's (MC) [4] (JPDF-MC) and Euclidean Minimum Spanning Tree (EMST) [5] (JPDF-EMST) closures, is evaluated alongside the MMC-based models MMC-IEM [6], based on Interaction by Exchange with Mean (IEM), and MMC-MC [7]. All four models show generally good agreement with experimental data for Flame D. In contrast, Flames E and F reveal more pronounced differences in terms of predicted scalar statistics and the local extinction behaviour. However, flame structures are generally well reproduced for Flame E, in particular by JPDF-MC and MMC-MC. The axial location of the most significant local extinction is also accurately captured by these models for Flame F though the extent appears under-predicted. The impact of the MMC formulation on the performance of the MC model is also investigated along with parametric sensitivities.

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