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Modelling turbulent lean premixed hydrogen flames under intensive strain rate

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The combustion community is increasingly focusing on hydrogen as a carbon-free fuel to address climate change. Burning hydrogen with low NO_x emissions requires lean premixed combustion, which is thermo-diffusively unstable and challenging to control. Effective and cost-efficient CFD-LES models with tabulated chemistry are essential to predict the interaction between turbulence and thermodiffusive instabilities and aid the design of future hydrogen combustion systems. This study evaluates a priori the performance of various two-dimensional manifolds on both unfiltered and filtered grids, using presumed β-PDF and FTACLES approaches. Alongside the well-established manifold of unstretched flamelets with varying equivalence ratio, this study introduces a novel low-dimensional manifold based on strained premixed counterflow flamelets with varying equivalence ratio at fixed strain. The DNS test case consists of a turbulent lean premixed hydrogen flame in a counterflow configuration, where the total strain rate results from both the nominal strain rate and turbulence-induced strain. Results indicate that two-dimensional, fixed-strain counterflow premixed flamelet manifolds significantly enhance the prediction of local reaction rates across the flame front, particularly at bigger filters.