International Conference on Numerical Combustion
Rome, Italy, October 14-17, 2025
www.icnc2025.com

Laminar premixed flame transfer functions of carbon-free fuels: comparison between flow solvers

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The computation of flame transfer functions, which characterize the global heat release response of flames to acoustic fluctuations, is of central importance to the assessment of thermoacoustic stability of a gas turbine engine. Carbon-free fuels such as hydrogen and ammonia are important to ensure sustainable power production using gas turbine engines with minimal greenhouse gas emissions. Since these fuels posses different reactivity and thermo-diffusive characteristics in comparison to natural gas, the nominal flame structure of these fuels are different from that of natural gas and therefore, also exhibit different dynamics. Furthermore, since fuels containing hydrogen exhibit higher diffusivities of mass in relation to heat, they are characterized by Lewis numbers smaller than unity. In the context of computing hydrogen flames, the non-unity Lewis numbers of the fuel calls for transport models which take into account the enhanced molecular diffusion of hydrogen. This paper answers an open question of how present-day computational fluid dynamics (CFD) solvers perform in the computation of the dynamics of hydrogen and ammonia-hydrogen flames and their corresponding dynamics. Computations of flame transfer functions (FTFs) of laminar premixed hydrogen and ammonia-hydrogen flames are performed using OpenFoam, ANSYS Fluent, S3D code of Sandia National Laboratories and the AVBP code from CERFACS. Transport models which take into account the enhanced molecular diffusion of hydrogen are used in each of these codes. The results show that despite using similar transport models and identical chemical mechanisms, quantitative differences in the laminar flame speed and the flame transfer functions are seen in each of the solvers. However, the qualitative features of the FTF remain the same. Specifically, the scaling of the FTF using a unique non-dimensional frequency parameter across different fuels and operating conditions is satisfied in the data obtained from the various solvers.