



Thermodiffusive instabilities in lean premixed hydrogen flames under gas turbine operating conditions: parametric variation of temperature, pressure, and forced perturbation

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A variety of problems arise with hydrogen combustion, such as flashback at a larger scale and intrinsic instabilities at a smaller scale. The thermodiffusive (TD) combustion instabilities originate from the strong differential diffusion of hydrogen, resulting from its Lewis number being lower than 1, which leads to significant flame wrinkling and strong irregularities in the flame front. In addition, the flame structures created by such intrinsic instabilities lead to enhanced flame speed propagation and higher consumption speed, accelerating flashback apparition. The interaction of such TD instabilities with turbulence has not yet been accurately predicted using present-day combustion models. Hence, this work constitutes the first step in characterizing and identifying TD instabilities of lean premixed hydrogen flames in Gas Turbine (GT) conditions. In this work, TD instabilities of lean premixed hydrogen-air flames are numerically studied, using two-dimensional Direct Numerical Simulations (DNS) combined with detailed chemistry, by identifying and comparing the characteristic patterns of TD instabilities in canonical cases. As a first step, to approach GT conditions even more, a reference case at ambient temperature and pressure is compared to a case at high pressure (20 bar) and a case at high temperature (800 K). Then, these cases are extended to injection of turbulence-like 2D fluctuations, using turbulence intensity and characteristic injection length based on values from experiments. The numerical results allow identifying the characteristic length scales of the flame front corrugation of such flames with the formation of flame fingers yielding strongly corrugated flames, resulting in 2.7 times faster consumption speed and 2 times increased flame area for the reference case compared to a 1D unstretched laminar flame. The TD instabilities lead to significant variations of the local reaction rates and temperature overshoot beyond the adiabatic flame temperature, which is especially more pronounced at high pressure than at high temperature. Finally, the results for the cases with velocity fluctuations reveal that the forced perturbation affects the TD instabilities formation by reducing the intensity level of the instability mechanism.