Thermoacoustic analysis of premixed methane–hydrogen flames in Open-ended tubes

ABSTRACT

Methane–air mixtures (ϕ =1.2) enriched with hydrogen at different concentrations (RH 0, RH 0.1, RH 0.2, RH 0.3 and RH 0.4) were ignited in an open-ended horizontal tube at 20 ◦C and atmospheric pressure of 1.013 bar. Flame propagation was filmed with a high-speed camera and the pressure captured to study the thermoacoustic interaction of flames at different hydrogen concentration. Two-thirds along the tube, the flames encountered an acoustic field and were subjected to longitudinal oscillations. Depending on the hydrogen content, significant differences were observed in the behaviour of the flames. For lower hydrogen concentrations (RH 0.1 – 0.3), the flame speed initially decreased as it entered the field, and was then subjected to violent oscillations, resulting in a high acceleration and speed. The accelerations were attributed by the formation of Rayleigh– Taylor instabilities, which existed in the form of spikes of unburned mixture into the burned gasses that coupled with the pressure oscillations. This satisfied the Rayleigh criteria that the acoustically driven instabilities require the heat release and pressure waves to be in phase. When the hydrogen content was increased, as the flame passed through the acoustic field, the flame speed decreased, and no Rayleigh–Taylor instabilities were observed, attributed to the higher flame speeds at RH 0.4. The main concern with high hydrogen addition to the existing natural gas infrastructure (for transportation or direct use by consumers) is mainly related with safety. The absence of violent oscillations in RH 0.4 flames shows that they do not increase monotonically with hydrogen addition, and may potentially be investigated further to be applied in existing natural gas infrastructures.