# Laminar flame propagation and instability investigations of transportation fuels in a high-pressure constant-volume cylindrical combustion vessel

**Yuyang Li**

*School of Mechanical Engineering, Shanghai Jiao Tong University, Minhang, Shanghai 200240, P.R. China*

(Email: yuygli@sjtu.edu.cn)

A high-pressure constant-volume cylindrical combustion vessel was designed to ensure the investigation of laminar flame propagation and instabilities over 298-500 K, 1-20 atm and a wide range of equivalence ratios for transportation fuels . A dual-direction-protection and self-sealing strategy was proposed to avoid quartz window damage and leakage at the static pressure up to 200 atm. Schlieren method with a high speed camera was applied to record the flame images. The nonlinear extrapolation method proposed by Kelley and Law was applied to obtain the laminar burning velocity (LBV). With this new apparatus, the laminar flame propagation of high boiling point fuels, such as aromatic fuels (benzene, toluene, ethylbenzene, *n*-propylbenzene), cycloalkane fuels (decalin), alkanes (*n*-heptane), alkenes (1-hexene and 1-heptene), alcohols (methanol, propanol isomers and butanol isomers) has been investigated under engine-relevant conditions. Apparent fuel molecular structural effects have been observed. For example, the LBVs of benzene, toluene and ethylbenzene demonstrate strong thermodynamic and kinetic effects, which can be attributed to the different C/H ratios of fuels and the ability to form benzyl radical. Also the LBVs of *n*-propanol and *i*-propanol demonstrate strong fuel isomeric effect, which can be attributed to the abilities of the isomeric fuels to produce reactive radicals (formyl, vinyl and ethyl) or stable radicals (methyl and allyl). A variety of flame instabilities can be observed in the laminar flame propagation of transportation fuels, such as hydrodynamic instability, thermal-diffusive instabilities (cellular instability and pulsating instability), buoyancy instability and forced acoustic instability. For the first time, pulsating instabilities were observed for high-boiling point fuels, as reported in an *n*-butanol/$O_2$/He flame at 20 atm. The cellular instability of spherically expanding methanol/air flames was found to increase from lean to moderate rich conditions, while the instability was found to decrease after $\phi > 1.4$. Stability analysis demonstrates the monotonically decreased critical Peclet number and the non-monotonically varied flame thickness result in the non-monotonic variation of cellular instability in methanol/air flames versus equivalence ratio. Forced acoustic instability was also generated with the addition of sound wave. Distortion on the flame surface can be observed after adding sound wave and the frequency of the sound wave was found to be most influential to the flame surface distortion.