Flame Acceleration and Deflagration to Detonation Transition in a Confined Geometry

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Abstract

Most industrial gaseous explosions involve the rapid acceleration of a flame ignited at a weak energy source. In the worst-case scenario, flame acceleration can lead to deflagration-to-detonation transition (DDT) resulting in catastrophic property damage and fatalities. In a laboratory setting, a channel equipped with obstructions is used to study flame acceleration and DDT. A review of the state-of-the-art in 2008 can be found in Ciccarelli and Dorofeev [1]. Flame acceleration is associated with an increasing volumetric burning rate that is governed by flame area enhancement. Key to flame acceleration is the expansion of the combustion products that leads to flow of the unburned gas ahead of the flame. In the earliest stage of flame acceleration, large-scale laminar flame folding occurs because of the unburned gas flow nonuniformity generated by the obstructions. As the flow velocity ahead of the flame increases, it leads to turbulence in the form of shear layers, boundary layers and larger recirculation zones behind the obstructions. Eventually compressibility effects become important and compression waves form ahead of the flame that eventually coalesce into a strong shock wave. The reflection of this shock off the boundaries produce reflected shock waves that interact with the flame leading to flame instabilities. At this stage, the combustion wave is referred to as a fast-flame, or choked-flame. Under certain conditions DDT occurs, generally because of shock reflection off an obstruction, producing a detonation wave that propagates at a velocity significantly below the Chapman-Jouguet (CJ) value. For a CJ detonation wave the velocity is governed by the mixture energetics, independent of reactivity; in an obstructed channel, the detonation velocity is governed primarily by the mixture reactivity and the boundary conditions. The present talk first provides a general background on detonation waves and outlines the current understanding of flame acceleration and DDT in obstructed channels. The mechanisms controlling flame acceleration, detonation initiation, and detonation propagation are outlined based on recent experimental results. The affect of detonation reaction-zone stability on the DDT run-up distance is discussed.

References

1. G. Ciccarelli and S. Dorofeev, Flame Acceleration and Transition to Detonation in Ducts, Progress in Combustion Science, 34(4): 499-550, 2008.