Numerical simulations of induction fronts with nearly-constant propagation speed

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Despite the prolific literature on the deflagration to detonation transition, see among others [1,2], the identification and analysis of the various physical mechanisms involved in the development of a detonation from a subsonic flame is still a challenge. Whatever the physical mechanism that initiates the flame acceleration (turbulence, flame instabilities, heterogeneities, etc.), specific effects due to the multidimensional characteristics of the flow may yield pressure waves or enhance their effects on the upstream gas promoting deflagration to detonation transition. Thus, the main objective of this study is the identification of two-dimensional mechanisms that promote the thermal runaway from subsonic initial conditions. The study focuses on compressibility effects neglecting the influence of dissipative effects. A global step chemistry is also considered to facilitate physical analysis. The subsonic flame considered in the present study is an induction front for which the propagation speed is controlled by setting appropriate initial conditions, see the pioneering work of Zel'dovich [3]. The interplay between these spontaneous ignition waves in a gradient of reactivity and pressure waves deserves to be further investigated. This key mechanism first needs to be analyzed in a one-dimensional configuration with initial conditions corresponding to a constant propagation velocity of the induction front. Depending on the ratio of this velocity with that of the sound speed, the analysis would lead to highlight a possible acceleration. Indeed, we focus on (i) the apparition of the pressure waves induced by the first ignition spot and its influence on the fresh gas, (ii) the piston effect of the induction wave propagating at a constant speed. The one-dimensional results of this work-in-progress validate the procedure for specifying the initial conditions and allow to highlight the relevance and limits of previous theoretical studies [1]. Eventually, the two-dimensional analysis uses these one-dimensional reference cases to identify specific geometrical conditions that promote the flame acceleration or possible transition to detonation. The simplified case of an interaction between two induction waves is investigated. This numerical study also allows a detailed parametrical study that will focus here on the heat release limit, the polytropic coefficient and the initial condition of the constant reactivity gradient.

References

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