

Galloping and Spinning Modes of Subsonic Detonation

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Abstract

It has long been observed that the presence of obstacles (tube walls, wire screens, solid particles, porous medium matrix, etc) may have a profound effect on premixed gas combustion. Apart from inducing hydrodynamic and thermal disturbances and thereby affecting the combustion wave speed, the obstacles also exert resistance to the gas flow causing reduction of its momentum. As has recently been realized the loss of momentum (drag) is of direct relevance to the explosive transition from deflagration to detonation and also to the hysteresic transition from supersonic sub-CJ detonation (quasi-detonation) to the pressure driven subsonic combustion wave dominated by convective effects [1-4]. The latter regime which may be referred to as 'subsonic detonation' is the main concern of the current study.

Perhaps the geometrically and physically simplest and yet experimentally quite feasible system for studying subsonic detonation is the filtration combustion. In this case, on one hand, the distortions introduced by the porous matrix may be ignored while, on the other hand, the resistance of the matrix to the gas flow is often so strong that one may neglect the inertial effects and take Darcy's law as the momentum equation. In this high drag limit the shocks are ruled out and the pressure nonuniformities are equalized not by the acoustic waves but rather through barodiffusion associated with low Reynolds number creeping flows. For many gas-porous medium systems the gas barodiffusivity exceeds its thermal diffusivity by several orders of magnitude thereby emerging as the principal transport agency controlling the reaction spread.

It is well known that the steady one-dimensional profile of conventional CJ detonation may easily lose its stability assuming a galloping, spinning or cellular structure. As will be shown in this presentation similar bifurcation is typical of subsonic detonation as well. Unlike the former, however, the subsonic detonation (due to its predominantly diffusive nature) constitutes a rather benign dynamical system, advantageous both for analytical and numerical explorations. Moreover, in a certain parameter range the problem of subsonic detonation becomes functionally identical to the problem of gasless combustion (self-propagating high temperature synthesis) known for its rich pattern-forming phenomenology involving among other things galloping and spinning structures as well as period doubling cascades and chaos [5-8].

References

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