Non-linear theory for the dynamics of shock fronts and cellular detonations in gases

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Abstract

The multidimensional dynamics of shock waves and gaseous detonations are discussed on the basis of analytical studies by comparison with experiments and numerical simulations.

The basic mechanism of cellular detonations is the coupling between the longitudinal oscillatory behavior of the exothermal reaction zone (galloping detonation) and the transverse propagation of disturbances along the lead shock. Analytical studies of both mechanisms will be revisited separately in two limiting cases. Strong shock waves and strongly overdriven regimes in the Newtonian approximation will be considered as well as Chapman-Jouguet regimes with small heat release (reactive transonic flow).

Recent experiments and DNS will be reported showing that the fish-skeleton, left by the markings of cellular detonations on the wall, can be reproduced by inert shock fronts that are initially wrinkled in a smooth sinusoidal form. An nonlinear study of the dynamics of such inert shock fronts will be presented showing the spontaneous formation of triple points (Mach stems) that propagate in the transverse direction. The coupling of this phenomenon with heat release then deciphers the pattern structure of cellular detonations.

The above mentioned theoretical results concerning inert shock fronts lead also to simple models for shock-vortex and shock-turbulence interaction. Some recent results will be presented and compared with DNS. The topology of the patterns on the shock front propagating in a turbulent flow is then compared to the structure of the turbulence. It will be shown that the characteristic cell size is much larger than the integral scale and has a tendency to increase with time. An analogy with the formation of large structures in the Universe will be given.

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