Influence of transversely supersonic inflow condition on the diffraction and re-initiation process for regular and irregular detonation wave

Hongbin Li, Jianling Li*, Cha Xiong, Wei Fan
School of power and Energy, Northwestern Polytechnical University, Xi'an, 710129, China
Corresponding author: lijianling@mail.nwpu.edu.cn

For the application of detonation wave in the supersonic propulsion, it is significant to initiate the detonation wave in the supersonic flow. In general, it is an effective and common way to initiate the detonation wave with the aid of a pre-detonator both in the static and supersonic flow. The outcome of detonation diffraction and re-initiation is not only decided by the geometry of confinement, but also decided by the characteristic of detonation wave, i.e. the stability between the detonation fronts in undiluted (unstable) and diluted (stable) mixtures. Moreover, the stability of detonation wave can be characterized as the observed degree of cellular regularity. Subsequent studies shown that the empirical correlation $d_c = 13\lambda$ breaks down in the regular detonation wave whose critical diameter for successful re-initiation can be up to 25λ or even bigger. d_c and λ refer to the minimum tube diameter above which a self-sustained detonation can transmit into an unconfined space without failure and the width of detonation cell respectively. Hence, the dominant mechanisms of detonation diffraction and re-initiation are different in two types of detonation waves. The diffraction and re-initiation processes have been widely investigated in the static and subsonic flows, however, the same phenomena have been little discussed in the supersonic flow.

In a confined channel filled with supersonic flow, the diffraction and re-initiation processes of two types of detonation waves, i.e. regular and irregular detonation wave, are numerically investigated. The pre-detonator is selected to initiate the detonation wave in the main channel, the supersonic flow is imposed from the channel inlet. The 5th order weighted essentially non-oscillatory (WENO) scheme and a two-step reaction model which can easily adjust the regularity of detonation wave are utilized in the simulations. It is shown that the re-initiation of both two types of detonation waves can be promoted, because the leading shock wave is enhanced by the supersonic flow at the upstream side. Compared with the minor promotion on irregular detonation re-initiation, the promotion of supersonic flow on the regular detonation re-initiation is more significant. The reason is that the decay process of leading shock wave is more quickly in irregular detonation diffraction than that in regular detonation wave, thereby any small decrease of initiation energy will have large influence on the diffraction process. Moreover, the effective local explosion centers are not provided by the supersonic flow outside the reflection zone. Hence, the supersonic flow has a minor effect on the irregular detonation re-initiation. However, the decay process of leading shock wave in regular detonation diffraction is slowly, and the transverse waves are gradually generated during its propagation in the channel. After the supersonic flow is imposed, the transverse waves are also generated even though the initiation energy is decreased.