Experimental and numerical investigation of the propagation of a shock-flame complex around a cylinder

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The present work focuses on the acceleration of a shock-flame complex and its transition to detonation arround a cylindrical obstacle in a rectangular channel.

A first experimental investigation was conducted using high speed schlieren visualization. Stoichiometric propane-oxygen mixture was used with the initial pressure from 5.5 to 9.7 kPa. The shock-flame complex was obtained by decoupling a detonation through a porous wall with a blockage ratio of 94.5

The formation of hot zones resulting from the interaction of several reflected shock waves and turbulent mixing in the wake of the obstacle were found to be responsible for flame acceleration. Local explosions leading to the formation of detonation was observed at low pressure after a first flame acceleration process at shock intersection on the walls and downstream of the obstacle. At higher pressure, the reflection of the incident shock on the obstacle is sufficient to initiate a detonation.

Two-dimensional inviscid numerical simulations were performed to complement the characterization of mechanisms involved in this configuration. A first case involved a simple shock wave interacting with a cylinder. It highlights the complex shock interactions, that would generate local hot zones, vortices, and acceleration of the flow , which in return could affect the flame front velocity respectively through chemical and mixing process, and advection. Other cases involving in addition a non-reactive, advected, density interface set behind the shock were performed. Compared to the shocked state, the density downstream this interface is smaller but the pressure is the same to mimic the burnt state resulting from a constant pressure deflagration. Quantitative data for this state was computed using NASA-CEA thermochemical code to fit the temperature of the burnt state that would result in the reactive case.

The simulation shows that diffraction of the first reflected on obstacle shock downstream of the interface leads to the formation of a high temperature spot at the meeting of three shocks on the walls. In some conditions for the reactive case, a detonation can thus be ignited. Otherwise, the increase of the flow velocity due to blast waves and local hot zones forces the flame to accelerate. Also, small perturbations on the interface give rise to a series of Richtmyer-Meshkov and Kelvin-Helmoltz instabilities, respectively upstream of the obstacle as it interacts with shock-waves, and downstream as it interacts with the backward flow in the recirculation zone. These instabilities provide mechanism for flame front acceleration by the increase of its surface. Moreover, its folding may lead to explosion due to combustion of unburnt gas pockets.

Quantitative description of these phenomenons and their influence in deflagration to detonation transition for this configuration will be the objective of future work, through a combined experimental and numerical investigation.

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