Shock-to-detonation transition due to shock interaction with prechamber-jet cloud

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Summary. A new principle of detonation initiation due to controlled interaction of a propagating shock wave (SW) with the cloud of hot explosive gas formed by prechamber flame jets in the stoichiometric propane–air mixture was demonstrated experimentally. Detonation initiation was shown to be conditioned by synchronization of cloud autoignition with its shock-induced compression.

1 Introduction

There exist two classical approaches for gaseous detonation initiation, namely, direct initiation with a strong source [1] and deflagration-to-detonation transition (DDT) [2,3]. In the course of direct initiation, a strong primary SW is generated. The temperature, pressure and compression phase duration in such an SW are sufficient for triggering fast exothermic chemical reactions in the close vicinity to the lead shock front. In this case, a detonation forms after a certain relatively short transition period. For the DDT, there is no need in the strong primary SW. The flame arising from a weak ignition source changes shape due to various instabilities and nonuniformities, thus leading to progressive thermal expansion of the reactive mixture and formation of an SW. After a certain relatively long transition period, autoignition of the mixture occurs in the region between the SW and the accelerating flame, leading to a detonation.

The other approach, different from those mentioned above, was suggested in [4, 5]. A possibility to initiate detonation due to acceleration of an initially weak SW by a travelling ignition pulse was demonstrated experimentally. In this case, fast exothermic reactions behind a lead shock front were triggered by the external ignition source rather than by the SW itself. The external ignition source, travelling with the SW, triggered chemical reactions in the explosive gas, thus promoting fast shock-to-detonation transition (SDT). In [4, 5], successive triggering of seven electric discharges, mounted equidistantly along the tube, was sufficient for initiating a detonation in the stoichiometric propane–air mixture at normal initial conditions at a distance of 12 to 14 tube diameters. A necessary condition for detonation initiation was careful synchronization of the triggering time of each electric discharge with the SW arrival to its position. The research outlined in this paper continues the studies reported in [4,5]. Contrary to [4,5], forced ignition of the reactive mixture behind the propagating SW was achieved using a classical prechamber [6] rather than a series of electric discharges.

2 Experimental Setup

Figure 1 shows the schematic of the experimental setup. The main elements of the setup are an SW-generator, straight detonation tube 60 mm in diameter and 3.5 m long, and