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APPLICATION OF NONEQUILIBRIUM NANOSECOND DISCHARGE FOR DETONATION INITIATION THROUGH A GRADIENT MECHANISM

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The study of nanosecond discharge application to initiation of gaseous detonation is related to the problem of pulsed detonation engine (PDE) concept realization. Detonation initiation through a gradient mechanism was theoretically introduced by Zeldovich [1], verified experimentally at low pressure [2], and, more recently, numerically studied in [3]. According to the work of Zeldovich, an ignition delay time gradient formed due to a corresponding temperature gradient leads to the onset of a spontaneous combustion wave. With the use of nonequilibrium plasma, an ignition delay time gradient can be created by combined heating and radical production by a volumetric discharge.

The discharge develops in a four–cell Plexiglas discharge chamber shown in Fig. 1. Each cell contains a pin–like high–voltage electrode (1) which is immersed into a 6.5 mm diameter channel (2). The length of the channels is 150 mm. The four channels are led into a square detonation tube (2×2 cm) through a converging reducer (3). The diameter of the channels inside the reducer is 9 mm. The convergence angle is 24 deg. The diameter of the reducer outlet is 20 mm, which matches with the inlet of the detonation tube. The reducer is manufactured of aluminium and is grounded, serving as the ground electrode. The whole Plexiglas discharge section is also covered with grounded shield (4). The shield includes a longitudinal gap for visual observation of the processes inside one channel. Discharge propagation is also enhanced by four grounded plates (5) which are fixed into narrow slits inside the chamber between the discharge channels. The plates stretch along the whole chamber, increasing the capacitance of the electrode system and the transverse reduced electric field in the channels. In comparison to the single–cell geometry in [4], the volume of the excited mixture may be up to four times larger.

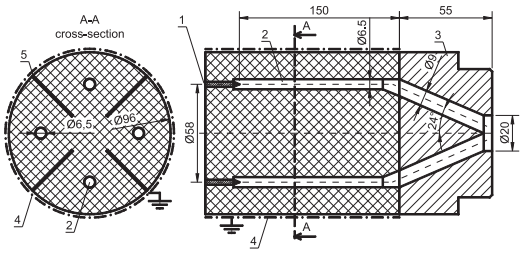

Fig. 1: Four–cell discharge chamber: the scheme. (1) — high–voltage electrode, (2) — discharge channel with a diameter of 6.5 mm, (3) — converging reducer, (4) — coaxial grounded shield, (5) — grounded plates.

A set of infra–red sensors (IR) and pressure transducers (PT) was used in the DDT experiments. The sensors are positioned 80, 170, 260, and 305 mm from the discharge channel outlet and the reducer inlet. The experiments were carried out in two different mixtures: C3H8 + 5O2 (undiluted) and C3H8 + 5O2 + 4N2 (40% nitrogen). The high–voltage pulse amplitude was 40—60 kV, the rise time was 20 ns, and the pulsewidth was 50 ns.

Under mixture pressure values in the range of 0.2–1 bar, the discharge developed as a streamer propagating in each of the channels. The energy input typically amounted to 0.2–0.3 J under these conditions. Under such low energy inputs only the gas in the region next to the high–voltage electrode was notably excited. The results of detonation initiation are presented in Fig. 2 in terms of x–t diagrams for different initial pressures. A CJ detonation wave was first observed at a minimum of 0.8 bar of initial pressure. Temporally resolved ICCD imaging confirmed the role of the gradient mechanism in detonation initiation. The spontaneous combustion wave originated from the region next to the high–voltage electrode and then accelerated along the channel with a longitudinal ignition delay time gradient.

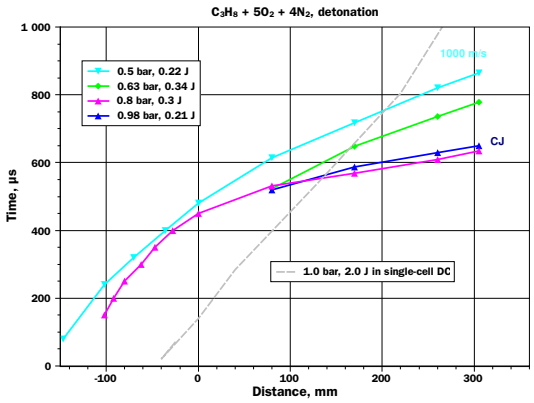

Fig. 2: X–t diagrams of DDT at various pressures. 40%–diluted mixture.

Reference

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