DETONATION IN STRATIFIED TWO-PHASE SYSTEMS "GASEOUS OXIDIZER – LIQUID FUEL FILM": THREE-DIMENSIONAL SIMULATION

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Abstract: The article presents the results of multidimensional numerical calculations of direct detonation initiation and deflagration-to-detonation transition (DDT) in horizontal flat channels of different height filled with gaseous oxygen under normal conditions and with films of n-heptane and n-decane applied to the lower wall. The determining role of liquid fuel volatility in the mechanism of film detonation propagation is shown. The mechanism of detonation propagation in the system with an n-heptane film is self-ignition of fuel vapors in the gas phase and in the system with an n-decane film, it is the mechanical destruction of the film, evaporation of the resulting microdroplets, and self-ignition of fuel vapors in the gas phase. It is shown that during DDT in channels of different height with an n-heptane film, preflame secondary explosions leading to DDT occur in a shock-compressed mixture of oxygen with preevaporated fuel near the leading shock wave (SW) but at a large distance from the film — in areas with elevated temperature and increased gas residence time. The SW velocity at the time of DDT is 800–900 m/s and the resulting detonation wave (DW) propagates at a speed exceeding 1300 m/s. At low ignition energies, there may be two limiting values of the channel height — minimum and maximum — at which DDT is still possible. The minimum channel height is determined by momentum and energy losses on the walls and the maximum is determined by the presence of an additional mechanism for evening the pressure in the flame.

Keywords: film detonation; direct detonation initiation; deflagration-to-detonation transition; three-dimensional mathematical simulation; microdroplets; n-heptane; n-decane

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Figure Captions

Figure 1 Lifting of microdroplets behind an air shock wave sliding over a film of liquid n-hexadecane: (*a*) $\mathrm{M} = 1.7$; and (*b*) $\mathrm{M} = 2.0$. The color of the droplets corresponds to their size

Figure 2 Comparison of calculated (solid curves) and measured [21] (signs) dependences of the lift height of liquid microdroplets on time after passing an air shock wave with a Mach number $\mathrm{M} = 1.7$ (*1*) and 2.0 (*2*)

Figure 3 Schematics of channels in experiments [32, 33]. The shaded wall corresponds to the film surface. Dimensions are in millimeters

Figure 4 Calculated dependences of the film detonation velocity on the distance traveled in a channel with a height of $H = 54$ mm: (*a*) n-heptane film; and (*b*) n-decane film. The dotted line corresponds to the film detonation velocity measured in [33, 36]

Figure 5 Calculated distributions of temperature, pressure, and mass fraction of fuel vapors in the DW sliding in a channel of height $H = 54$ mm over films of n-heptane (*a*) and n-decane (*b*). The dots show microdroplets above the film surface. The arrows show the beginnings of energy release zones

Figure 6 Calculated dependences of the leading shock wave velocity on the traveled distance during DDT in channels 24 (dotted curves) and 54 mm (solid curves) high with n-heptane films at an ignition energy of 5 (gray curves) and 10 J (black curves). The arrows show the conditional values of the DDT run-up distance L_{DDT}

Figure 7 An example of calculated three-dimensional distributions of pressure and flame front surface in a channel of height $H = 54$ mm with a film of n-heptane at the initial stage of flame propagation: $t = 1$ ms after ignition

Figure 8 Calculated distributions of temperature, mass fraction of fuel vapors, and normalized rate of preflame reactions during DDT in a channel of height $H = 54$ mm with n-heptane film: (*a*) initial stage of flame propagation; (*b*) immediately prior to DDT; and (*c*) immediately after DDT. The dots show microdroplets above the film surface. Ignition energy is 5 J

Figure 9 Calculated temperature distribution in a channel of height $H = 54$ mm with a film of n-heptane at an ignition energy of 0.1 J. The dots show microdroplets above the film surface

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