Propagation of Detonation Wave in the Encumbered channels

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Examination of initiation and propagation of detonation is one of fundamental branch of the gas dynamics. Detail information about features of these processes is very important for solving the problems connecting both with prevention of detonation regimes of combustion to increase the blast safety and with applications of detonation to technological processes. In the present research the numerical investigation of detonation propagation in the plane encumbered channels filled by stoichiometrical hydrogen-air mixture under normal conditions is carried out. Detonation was initiated by the electrical discharge of narrow layer form. It was supposed the electrical energy is transformed instantaneously into internal energy of gas mixture.

The system of equations describing plane two-dimensional flows of non-viscous gas mixture is as follows:

$$\frac{\partial \rho}{\partial t} + \frac{\partial (u\rho)}{\partial x} + \frac{\partial (v\rho)}{\partial y} = 0$$

$$\frac{\partial (\rho u)}{\partial t} + \frac{\partial (\rho u^2 + p)}{\partial x} + \frac{\partial (\rho u v)}{\partial y} = 0$$

$$\frac{\partial (\rho v)}{\partial t} + \frac{\partial (\rho v u)}{\partial x} + \frac{\partial (\rho v^2 + p)}{\partial y} = 0$$

$$\frac{\partial (\rho (u^2 + v^2)/2 + \rho h - p)}{\partial t} + \frac{\partial (u(\rho (u^2 + v^2)/2 + \rho h)}{\partial x} + \frac{\partial (v(\rho (u^2 + v^2)/2 + \rho h))}{\partial y} = 0$$

$$\frac{\partial (\rho n_i)}{\partial t} + \frac{\partial (u\rho n_i)}{\partial x} + \frac{\partial (v\rho n_i)}{\partial y} = \rho \omega_i ,$$

where x and y are the Cartesian coordinates; u and v are the corresponding components of velocity; t is time; ρ, p and h are density, pressure and enthalpy, respectively; n_i is the molar concentration of the i th component of mixture; ω_i is the rate of formation/depletion of the i th component.

The equations of state for the hydrogen-air mixture have the usual form

$$p = \frac{\rho RT}{\mu},\ \ h = \sum n_i h_i(T),\ \ \mu^{-1} = \sum n_i,\ \ i = 1, 2, \ldots 8\,.$$

Here T is the temperature, R is the universal gas constant. The values of the partial enthalpies $h_i(T)$ are borrowed from [1].

The set of gas dynamic equations jointly with the set of chemical kinetic equations [2], which takes into consideration principal features of chemical interaction of hydrogen with oxygen, was solved by a finite-difference method based on the Godunov's scheme [3].

Results

1. The propagation of detonation wave initiated by the discharge of narrow layer form near the closed end of channel of constant width was examined. It has been established that the plane detonation front is curved with time and the cellular detonation structure is formed (fig.1). Let us note that the transversal size of detonation cell does not depended on the channel width under other conditions being equal (fig.2). This fact is made agree with the experimental research [4].

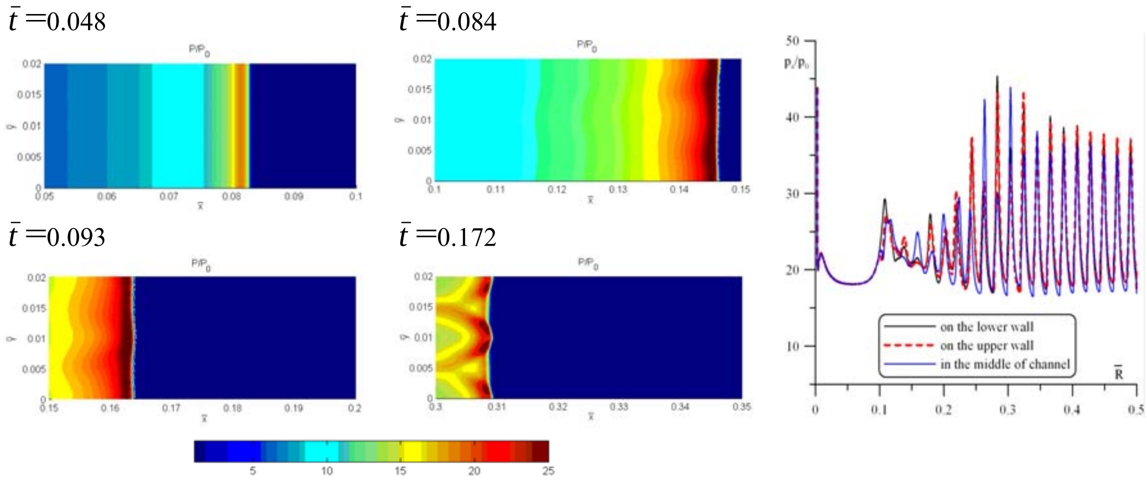

Fig.1. *Formation of cellular detonation in the plane channel.*

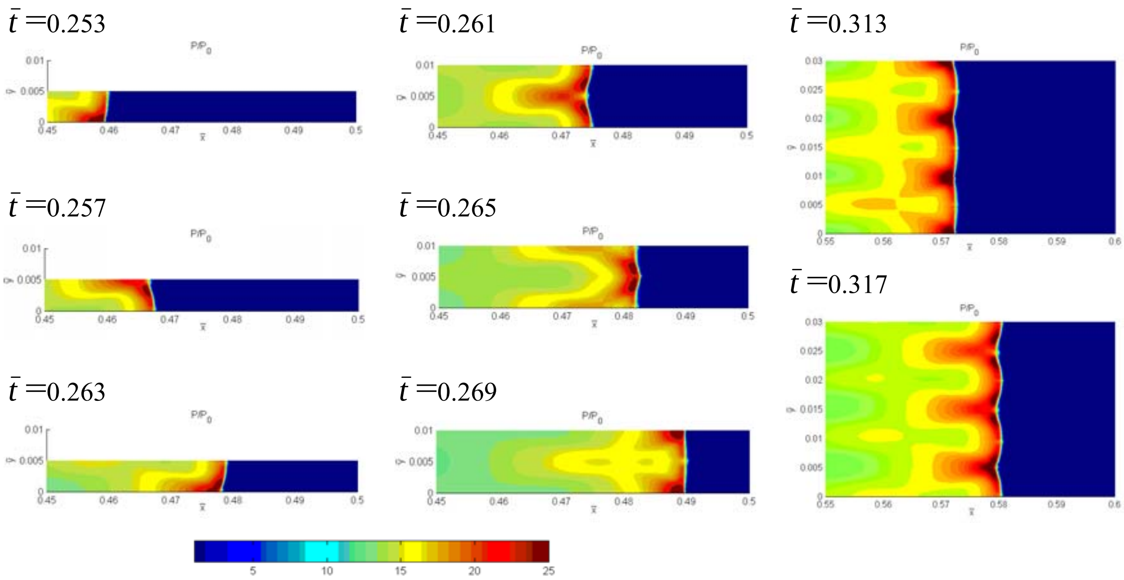

Fig.2. *Formation of cellular detonation in the plane channels of different width.*

2. The propagation of detonation wave in the channel containing transversal undestroyable rigid wall of height $\bar{l}_w$ ($\bar{l}_w$ is smaller than channel width) was examined. It has been obtained that detonation regime of combustion is remained after the interaction with the obstacle under conditions that if wall height does not exceed some critical value (fig.3).

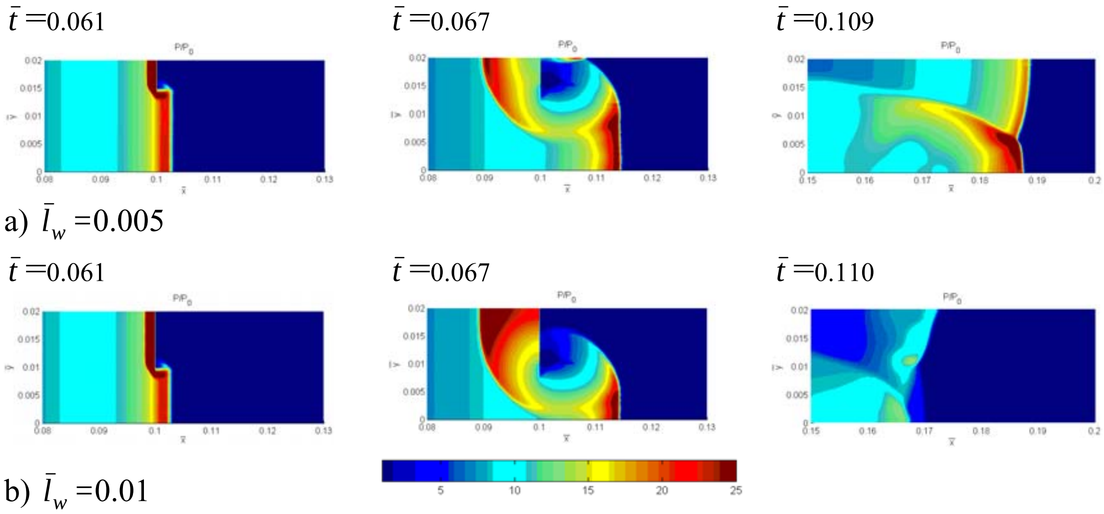

Fig.3. *Conservation (a) and destruction (b) of detonation in the channel with the undestroyable transversal obstacle.*

In the case of destroyable rigid wall the influence of wall existence time to the conservation of detonation regime was analysed. It has been established that in the case when $\bar{l}_w$ is greater than critical value the detonation wave is remained in channel if rigid wall existence time $\bar{t}_w$ does not exceed some critical value (fig.4).

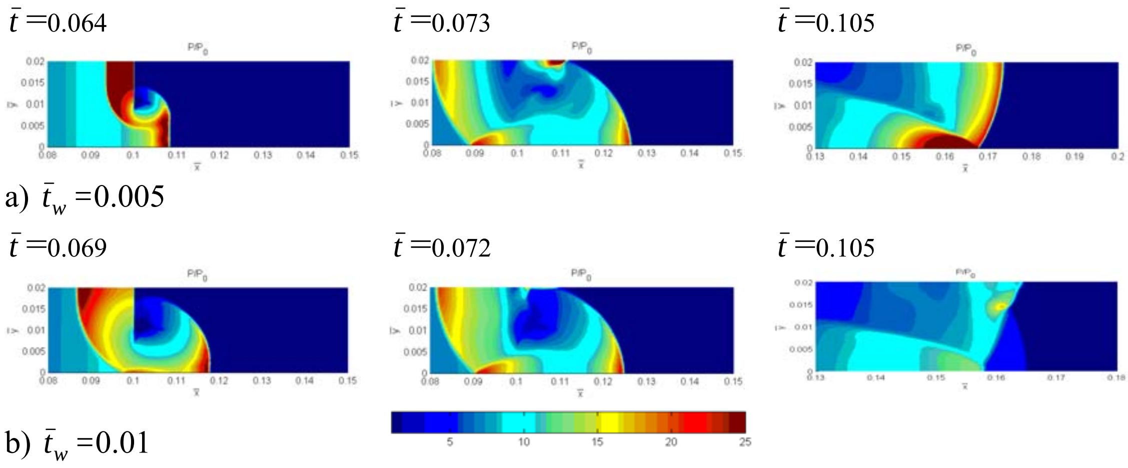

Fig.4. *Conservation (a) and destruction (b) of detonation in the channel with destroyable transversal wall of height* $\bar{l}_w$ *=0.01*

3. The numerical calculations of detonation wave propagation in the plane channel containing the internal rigid wall of length $\bar{l}_1$, which is parallel to upper and lower channel walls, in the case of detonation initiation by the energy input in the layer near the closed end of narrow part of channel was carried out too. Moreover, it was supposed that additional rigid wall with

slot of width $\bar{L}_3$, which is perpendicular to the internal one, is situated in the channel on the distance $\bar{l}_2$ ($\bar{l}_2 > \bar{l}_1$) from the closed channel end (the difference between channel length $\bar{l}_2$ and length of the internal wall $\bar{l}_1$ is not great).

When the slot is absent ($\bar{L}_3$=0.0) it has been established that if the width of narrow part of channel $\bar{L}_1$ is smaller than the critical channel width for the detonation transition into the unconfined space, then the detonation wave ("back" detonation) is formed in the part of channel of width $\bar{L}_2$ when the last is not greater than some critical value (fig.5). For the value $\bar{L}_2$, that is smaller than critical one, the influence of the slot width on the formation of "back" detonation was examined. It has been obtained that the detonation wave is formed too in the part of channel of width $\bar{L}_2$ if the slot width is not greater than some critical value (fig.6).

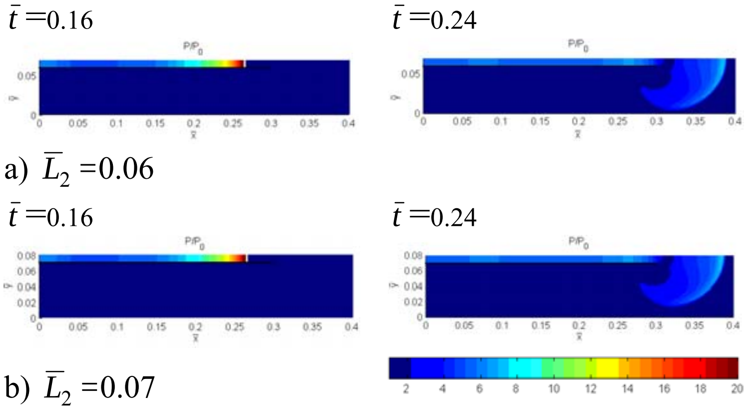

Fig.5.

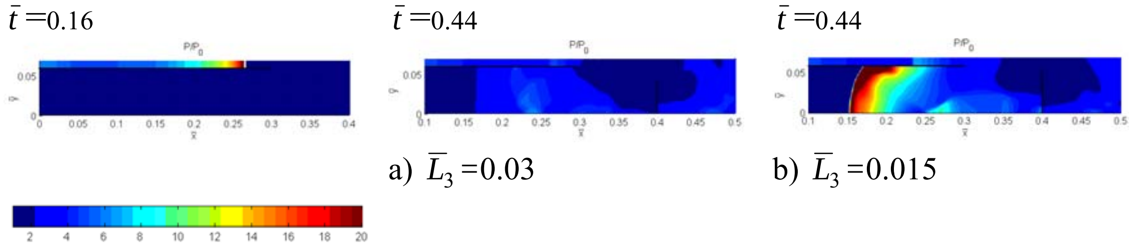

Fig.6. $\bar{L}_2$ =0.06

This work has been supported by the Russian Foundation for Basic Research (Grant No. 02-01-00110), by the President Grant for Support of Young Russian Scientists and Leading Science Schools of Russian Federation (No. НШ –1635.2003.1, No. МК-1716.2004.1).

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