Detonation Initiation by the Electrical Discharges in the Plane Channel

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In the present research the numerical investigation of detonation initiation by the electrical discharges in the plane channel of constant width filled by stoichiometrical hydrogen-air mixture under normal conditions is carried out. 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:

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

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

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

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

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

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 initiation of detonation wave near the closed end of plane channel of constant width $\bar{l}$ by the electrical discharges of various configurations under constant area of energy release domain was examined (fig. 1).

Fig.1. *The configurations of discharges used for initiation of detonation:*
a) The narrow layer near the closed end of channel;
b) The elongated rectangular discharge near the closed end of the channel.

It has been established that the minimal value of critical energy of initiation E_* is obtained when the discharge has the form of narrow layer near the closed end of channel (fig.2). In this case the plane detonation front is curved with time and the cellular detonation structure is formed (fig.3). In the case of detonation initiation by the elongated rectangular discharge the front of detonation wave has initially the form of detonation cell, which is transformed after some time to the cellular detonation front as in the case of discharge of narrow layer form. According to the calculations the transversal size of detonation cell does not depended on the channel width. This fact is made agree with the experimental research [4,5].

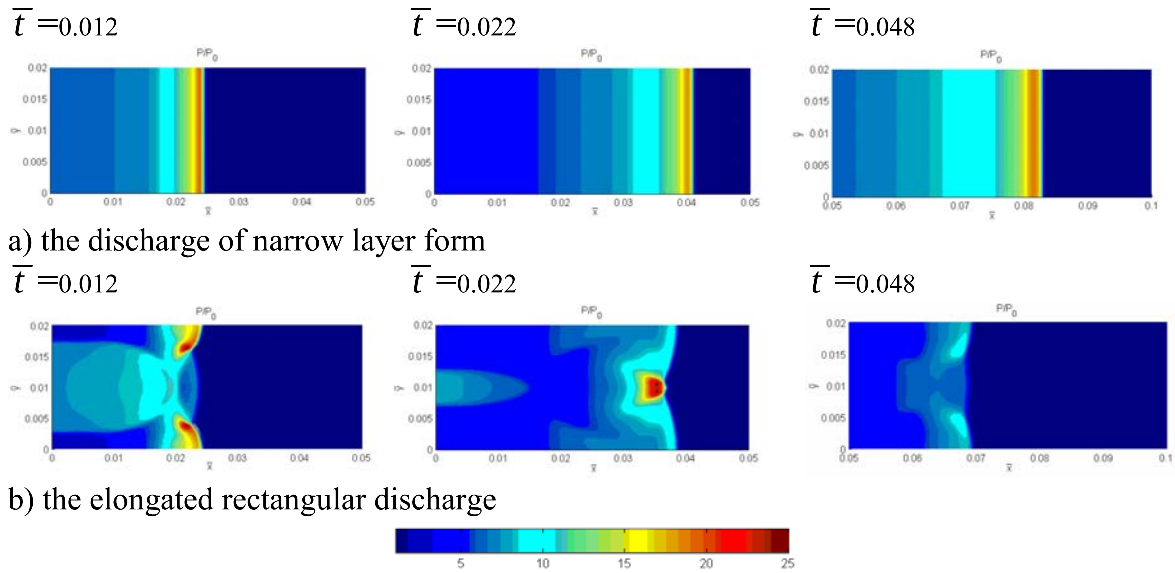

Fig.2. *Time variation of pressure field in the case of critical energy input for initiation of detonation by the discharge of narrow layer form* E_*.

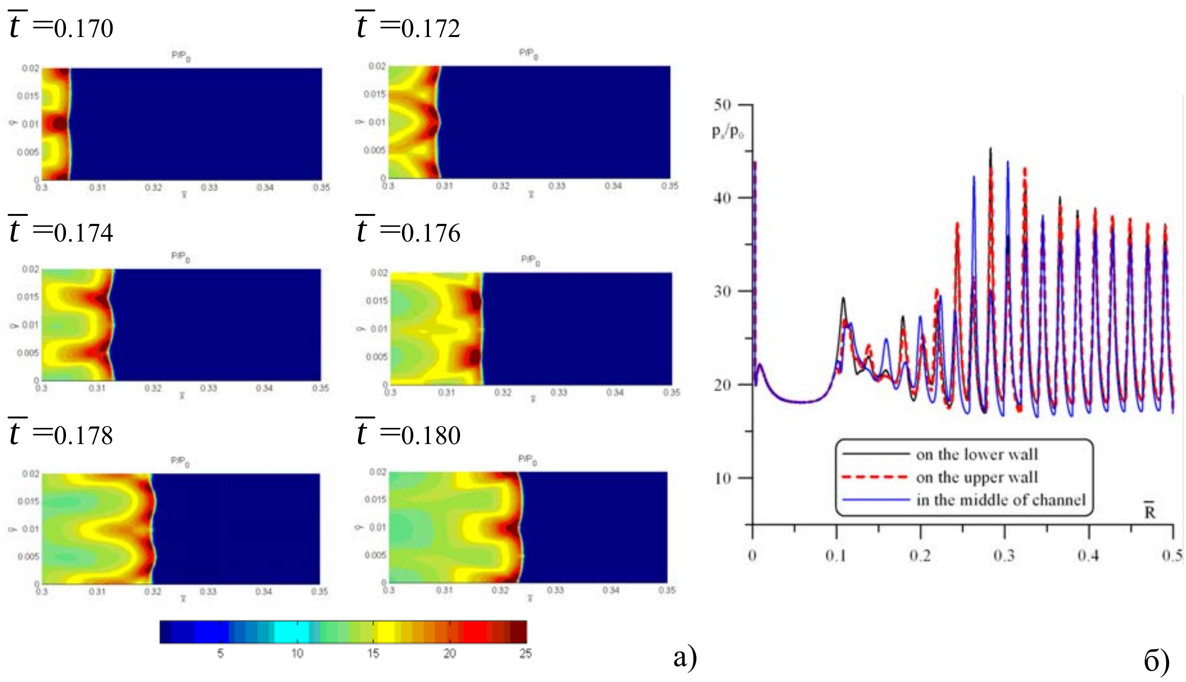

Fig.3. *Time variation of pressure field (a) and the pressure dependencies from the wave coordinate at the some points of front (b) in the case of detonation initiation by the discharge of narrow layer form.*

2. The possibility of decrease of critical initiation energy E_* by means of use the several electrical discharges has been investigated. According to the described above results the discharge of narrow layer form with the subcritical energy E_0 was used as the initial one. It has been established that in the case, when the additional discharge has the narrow layer form also (fig.4a) and is situated at the definite distance from the closed end of channel, the detonation wave is formed under the subcritical total energy input (fig.5).

It was obtained that the replacement of additional discharge of narrow layer form to the additional one that represented on the fig.4b leads to the increase of total energy of initiation of detonation in the channel under consideration.

It was established that the critical energy of detonation initiation can be decreased by the use of several additional discharges behind (or before) the leading shock front at time moments when the temperature on the wave front becomes lower than some value (fig. 6).

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).

a) b)

Fig.4. *The configurations of additional discharge.*

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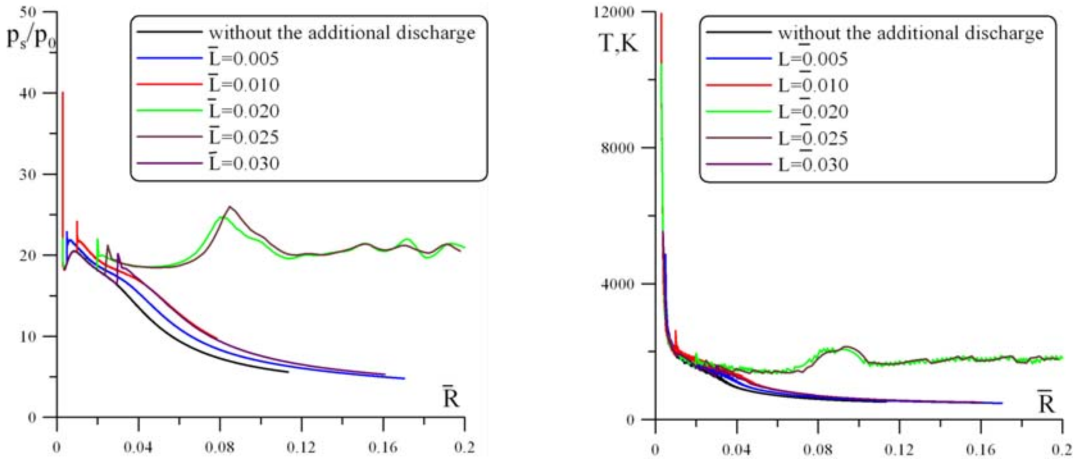
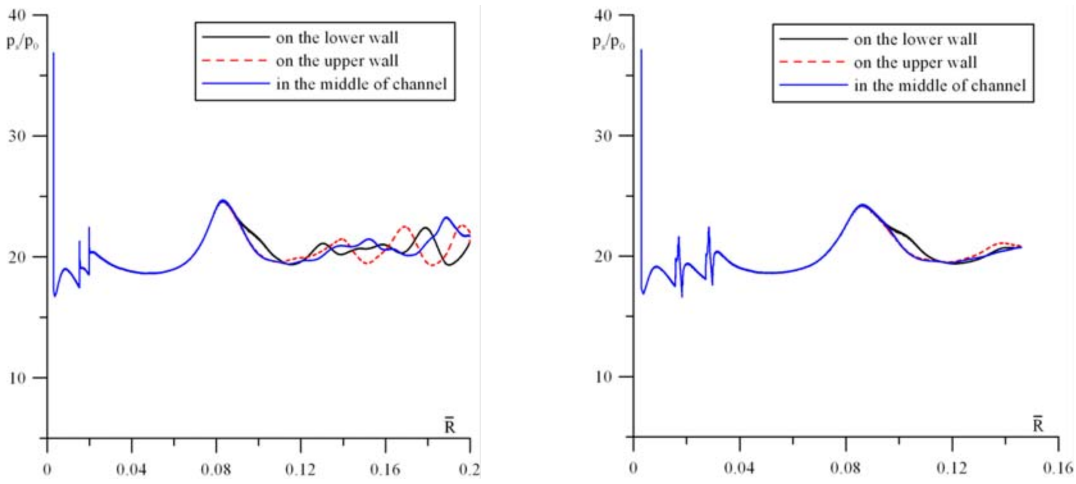


Fig.5. *The pressure and temperature as functions of the wave coordinate for several positions of additional discharge under* $E_0 = 0.913\,E_*$ *and* $E_{add} = 0.062\,E_*$ *(*E_{add} *– energy of additional discharge).*



a) $E_0 = 0.837\,E_*$ *and 2 discharges with* $E_{add} = 0.0625\,E_*$

b) $E_0 = 0.844\,E_*$ *and 2 discharges with* $E_{add} = 0.056\,E_*$

Fig.6. *The pressure dependencies from the wave coordinate at some points of front in the case of two additional discharges with energy* E_{add} *behind (a) and before (b) the leading shock front.*