PROPAGATION of a MULTIFRONT DETONATION ALONG a CONVEX SURFACE

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Abstract. Experimental data on diffraction of multifront detonation wave (DW) on a convex segment of radius R_0 and on quasi-stationary propagation of multifront DW along curvilinear gas layer are presented (layer creates around of a cylindrical surface). It was established that in the weakened wave new re-initiation centers arose periodically on some distance from diffracted surface (within the limits of a gas layer thickness). Being located on some distance from curvilinear boundary such micro-centers «turn» DW to an internal wall and the more ensure a self-sustaining propagation of DW along curvilinear boundary. A simple model for estimation of critical gaseous layer thickness is proposed.
Keywords: initiation, detonation, diffraction, curvilinear boundary, detonation engine, external combustion

Introduction. At transition of a detonation wave (DW) from the channel of constant cross-section to the extending channel the arising rarefaction waves (RW), influencing on DW, transforms it in a non-stationary mode and comes to or DW attenuation, or DW re-initiation. Such regimes realized depending on a ratio of the characteristic channel size and the DW cell size (at variation of initial pressure). The local centers (one or several) of natural or artificial ignition of a mixture are the basic reasons of DW re-initiation (at the expense of the finishing of an induction period or of the collisions of weakened disturbances).

It is necessary to note, that up till now the processes of multifront DW propagation along convex curvilinear boundary practically were not analyzed in the numerical calculations and not investigated experimentally.

The elementary convex curvilinear boundary is a circle of radius R_0. Along such curvilinear surface a self-sustaining propagation of classical DW with smooth front and radial orientation (normal to boundary) is impossible, as tangential DW speeds on internal and external boundaries of a gas layer should be non-equals.

The basic task of experimental researches of presented paper is the determination of the physical mechanism of «turning» of multifront DW at its propagation along a curvilinear gaseous layer for which a cylindrical surface of radius R_0 is the main boundary (external gaseous layer around cylinder).

Experiment.

Series 1 - classical diffraction of stationary multifront DW on a convex segment of radius R_0. Width of the initial flat channel *l* and radius of curvature of a segment R_0, and also characteristic cell size *a* (at changing of initial pressure P_0 of a mixture) are varied.

Series 2 - direct initiation and quasi-stationary propagation of multifront DW along curvilinear gas layer created around of a cylindrical surface. Surface radius R_0 (radius of internal boundary of a curvilinear gaseous charge) and cell size *a* are varied.

The basic results.

Series 1. At the fixed geometry and the channel sizes the failure of multifront detonation structure and transition to a mode of high-speed turbulent burning is observed in the extending channel at rather small P_0, and DW re-initiation is observed at appreciable large P_0 (Fig. 1).

Series 2. The following modes are observed depending on initial mixture pressure P_0:

a) mixture ignition near to an electrode and subsequent complete failure of detonation and deflagration on some distance from an electrode at low P_0 (Fig. 2);
b) galloping detonation in the circle-like channel with external curvilinear wall when typical process «DW-excitation – DW-attenuation» cyclically repeats: after DW removal from an electrode and its transformation to a mode of turbulent burning, new DW is formed in some area of the channel near to external boundary by an explosive image (Fig. 3);
c) stationary DW-propagation in a circle-like channel (Fig. 4);
d) DW re-initiation in circle-like free gaseous charge (without wall on external boundary or its negligible influence) and quasi-stationary «turning» of curvilinear surface by a DW (Fig. 5).

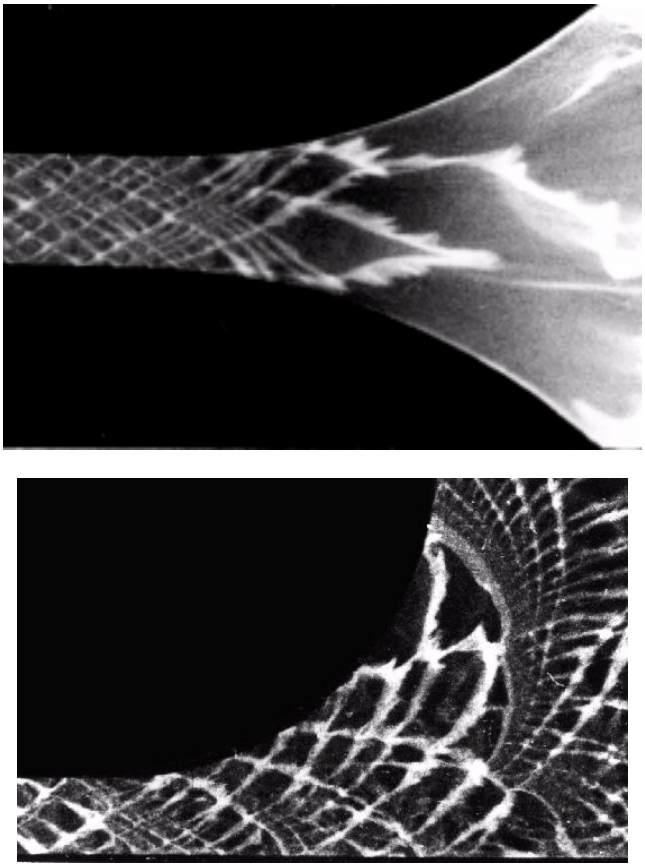

Fig. 1. Self-luminosity photograph of DW-attenuation (upper) and DW-re-initiation (lower) (propagation from left to right) at diffraction of multiheaded DW on boundary with radius R. The re-initiation centers are the areas with small cell sizes in divergent flow.

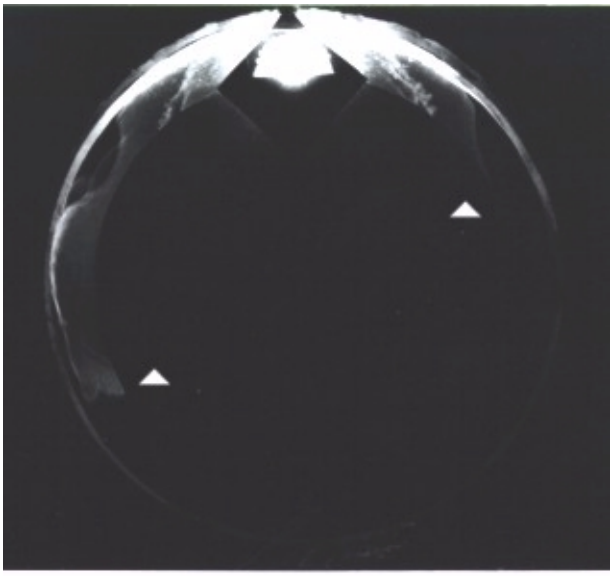

Fig. 2. Self-luminosity photograph of whole destroying of detonation and deflagration regimes (propagation in two direction from initiation point) in curve channel of constant cross-section (radiuses R_1 and R_2). The points of luminosity destroying remarks as triangles.

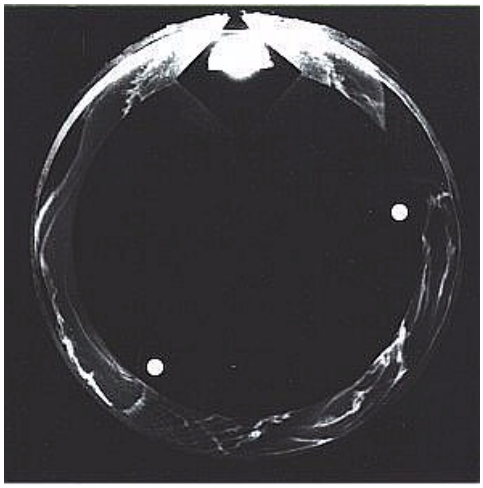

Fig. 3. Self-luminosity photograph of galloping DW-propagation (left DW-rotation from initiation point) in curve channel of constant cross-section (radiuses R_1 and R_2). The re-initiation centers are marked as light points.

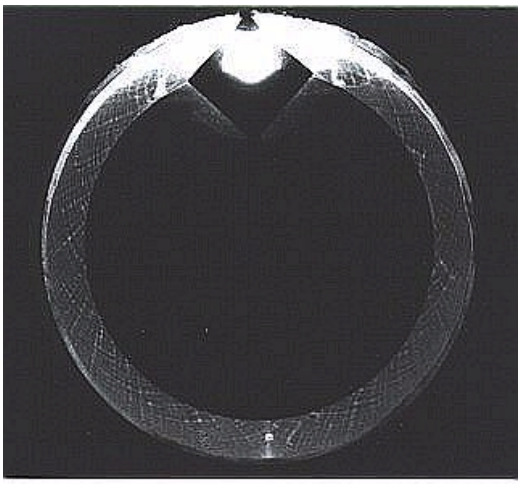

Fig. 4. Self-luminosity photograph of stationary DW-propagation in curve channel of constant cross-section (radiuses R_1 and R_2).

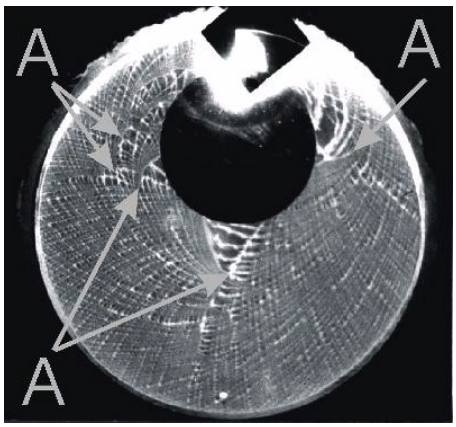

Fig. 5. Self-luminosity photograph of DW-rotation (on right) around curvilinear surface of radius R: the re-initiation centers are marked arrows A.

Criterion of quasi-stationary DW propagation around of a curvilinear surface. For quasi-stationary propagation of a multifront detonation wave along curvilinear convex surface it is necessary, that in the weakened wave new re-initiation centers arose periodically on some distance from diffracted surface (within the limits of a gas layer thickness). Being located on some distance from curvilinear boundary such micro-centers will be «to turn» DW to an internal wall.

Mathematical model and its consequences. The elementary mathematical model for an estimation of the minimal thickness of a gaseous layer l_* through geometrical parameters of curvilinear surface and physic-chemical parameters of a combustible mixture is proposed. Some consequences of model are the next: at fixed R_0 the increase of chemical activity of a mixture or the increase of initial pressure results in decreasing of necessary thickness of a gaseous layer; at the same time the decrease of R_0 at fixed P_0 is accompanied by increase of necessary thickness of a gaseous layer for quasi-stationary propagation of DW. On Fig. 6 the calculated data are presented for angle χ among neighbor re-initiation centers as function of ratio of critical layer thickness $0.5l_*$ to boundary radius R.

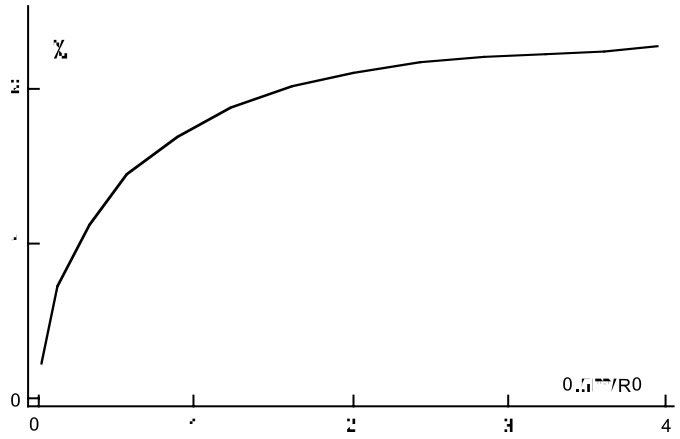

Fig. 6.

The conclusion. The main results of investigations are the next:
a) the quasi-stationary modes of multifront DW-«turning» on a convex curvilinear surface are found experimentally;
b) it is established, that the basic reason of stationary DW propagation along curvilinear convex surface is connected with periodically arising micro-centers of DW re-initiation on some distance from diffracted boundary;
c) the mathematical estimation is offered for determination of the minimal thickness of a gaseous layer necessary for quasi-stationary rotation of a multifront detonation in a free gaseous circle-like layer;
d) the consequences of mathematical model are confirmed by experiments.