Blast Waves Focusing In Hydrogen – Air mixtures

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Previous investigations [1-5] show that the formation of the so-called «hot spots» (HS) in combustible mixture is peculiar to the process of transition from deflagration to detonation. The governing parameters of HS are: the size of zones, temperature distribution inside HS, the pressure, and the concentration of reactive component. These parameters control the self-ignition of combustible mixtures, the mode of explosive transformation, and the possibility of detonation development.

Recently, of interest becomes the way of creation of hot zones due to shock waves focusing, i.e. the process of their interaction with non-flat reflective elements in shock tubes. The zones of the high reactivity are realized without additional external influence on the flow. However, the development of process occurs in moving, perturbed and non-uniform gaseous environment. With the reference to DDT problem, the question on stability of detonation waves propagating in gaseous combustible mixture with variable parameters is of high priority. The critical parameters of detonation stability depend on the absolute temperature and magnitude of temperature gradient inside non-uniformity. The response of a detonation zone to the density or the pressure in non-uniformity (at constant temperature) is basically connected to amplification of nonlinear perturbations at the hydrodynamic front.

The results of investigation of the interaction of shock waves with non-flat reflectors as well as self-ignition of hydrogen - air mixtures due to focusing at three-dimensional and two-dimensional reflectors are described in [1-5].

In these cases the shock wave before the interaction with the LPC end-flange propagates with constant speed, so there is an area of constant parameters behind wave front. On the first stage of investigation such an approach is useful for the comparison of regimes of explosive transformation caused by interaction of shock waves with flat and non-flat reflectors.

At the following stage of research seems to be pertinent to investigate the initiation of combustion and detonation as a result of non-stationary shock (blast) waves effect. Such waves are formed in shock tubes when the rarefaction wave overtakes the shock wave. Distinctive feature of blast waves is the continuous variation of pressure and temperature behind front of a wave. The experimental data on interaction of blast waves with flat end-flange were obtained in [6] in laboratory installations. In [6] the theoretical calculations of blast waves were carried out. The study of interaction of blast waves with non-flat reflectors allows estimating the influence of flow non-steadiness on transition of slow combustion to detonation.

Experiments have been carried in laboratory shock tube. The LPC (1 on the scheme Fig .1a) had a circular cross-section of ∅ 50mm. The length of LPC was the same in all tests L = 1.1 m. The HPC (2 on the scheme Fig.1a) had the same cross-section size, but the length L = 0.07 m. The initial air pressure was P_1 = 1 bar in LPC. The pressure P_4 of the HPC was limited to 100 bar. Helium was used as a driver gas. The HPC gas was initially separated from the LPC gas by hermetically mounted self-bursting diaphragm (3 on the scheme Fig.1a) .The pressure profiles of the incident blasts in LPC with open end exit were monitored by means of the two flush-mounted piezoelectric gauges located along LPC as on scheme Fig.1. The data acquisition system consisted of fast card T-512 installed in PC unit . The software supplies the presentation of data in graphical mode, preliminary processes data and saves both in graphical a text modes.

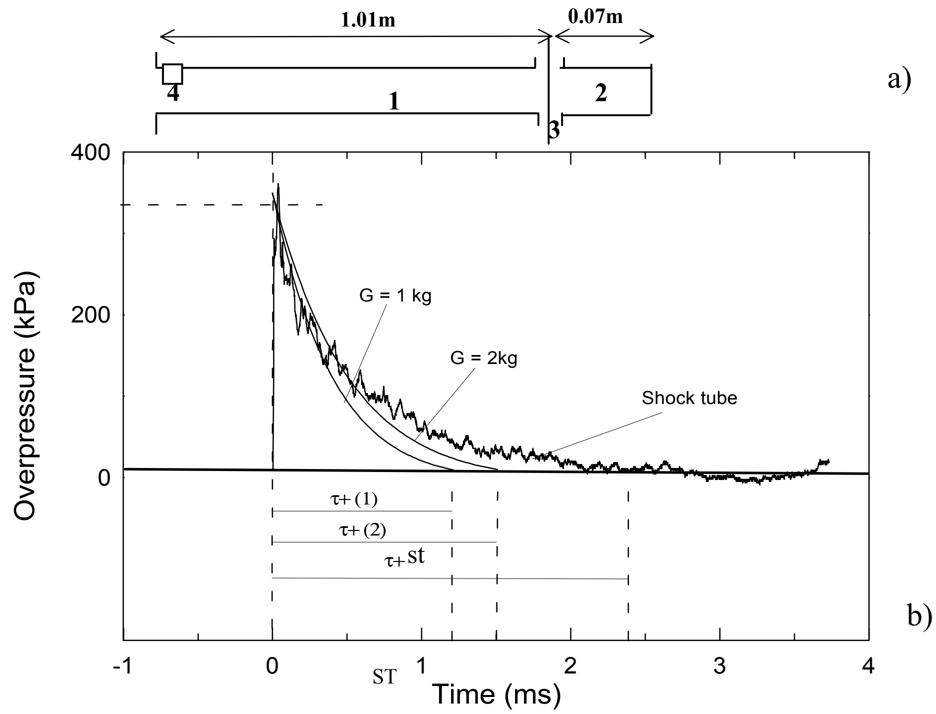

Fig. 1 Pressure histories recorded in a shock tube in comparison with HE explosion.

Fig. 1.b gives an example of measured pressure profiles behind blast wave with Mach number $M \approx 2$. The attenuation of such wave is insignificant on the distance ≈ 50mm. Pressure profile presented in fig.1b was obtained by PG4. The pressure profiles demonstrate the realty of blast wave propagation near the shock tube exit. The amplitude of blast was $\Delta P = P_2 - P_1 \approx 3.5$ bar (or $\Delta P^* = \Delta p / P_1 \approx 3.5$) with the duration of positive pressure phase $\tau_{+st} \approx 2.3 \cdot 10^{-3}$ sec (τ_+ (1) – for HE charge 1 kg, τ_+ (2) – for HE charge 2 kg).

As follows from presented experimental results blast waves with decaying pressure can be generated in shock tube with ultra-short HPC. In the range of blast wave Mach numbers $1.5 < M < 2.5$ the acceptable similarity exists between spherical blast waves driven by HE –burst with charge weight G and planar blast driven by the axial expansion of pressurized gaseous volume with definite linear sizes.

However the data on the effect of shock waves generated from HE explosions on hydrogen-air mixtures are absent. For this reason the possibility and the specific features of hydrogen-air ignition by explosive waves formed as a result of detonation of the real HE charge have significant scientific and practical interest.

The scheme of experimental setup is presented in Fig.2. To focus the blast wave the two-dimensional reflectors (corners) with an apex angle 90^0 were used. Length of the reflectors lateral side was 10 cm and 50 cm. The reflectors were located in a cubic box with the side length approximately 90 cm. The wall opposite to the charge was covered by thin (50 μm) film. The vertical wall directed to the recording equipment was done from transparent plexiglas.

To record the pressure history at the wall and in the apex of reflector the gauges PCB were used. In a reflector with the side 50 cm four gauges (1-4) were used, and in a reflector with the side 10 cm only two gauges (1 and 3) of pressure (gauges arrangement is shown in Fig.2).

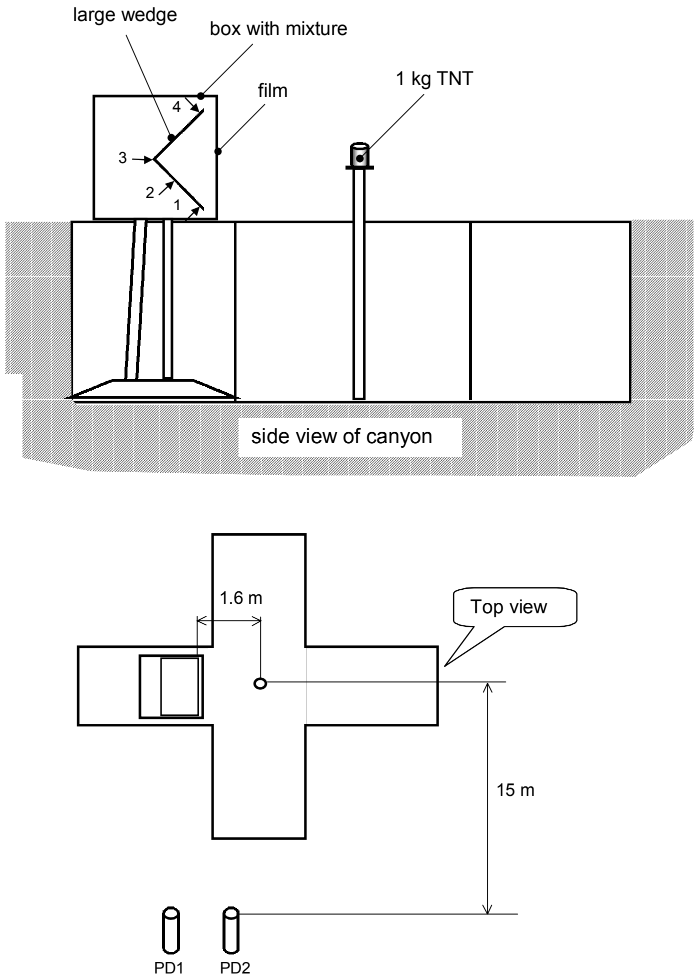

Fig.2 Scheme of the experimental facility for study of hydrogen-air combustion under conditions of blast. 1-4 – pressure transducers (PCB type)

To record the radiation in the course of interaction between blast wave and hydrogen-air mixture two photodetectors PD1 and PD2 were used, located, as shown in Fig.2. PD2 was directed to the volume, adjacent to the opening of reflector (at the distance 0.5 м from the entrance section). PD1 was directed to the inner cavity of a reflector.

The hydrogen-air mixture inside the reflector was created by pumping of necessary amount of hydrogen in a box. Uniformity of the mixture was maintained by hashing of gas inside a box with the help of the fan. The concentration of hydrogen in the mixture was controlled by the value of sound speed measured by the microphone gauge

Boundaries of the areas of explosive modes for wedge reflector with an apex angle of 90^0 are shown in Fig.3, where the incident shock wave Mach number is plotted as a function of hydrogen percentage in air.

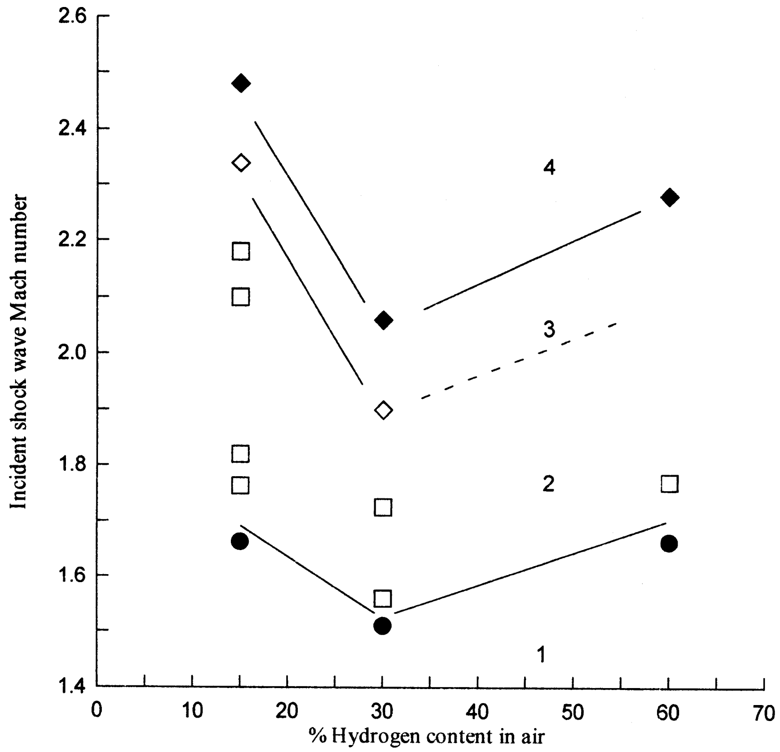

Fig.3 Areas of explosive modes for wedge reflector with a corner 90^0.
1: no ignition, 2: mild ignition, combustion, 3: transition zone,
4: strong ignition, detonation.

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