Dynamics study of detonation wave cellular structure

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The detonation cell size is one of important scale parameters characterizing the detonation wave properties (Oppenheim and Soloukhin 1973, Lee 1984). In spite of a large amount of researches, there is no so much information on dynamic properties of cellular structure when detonation wave propagates sufficiently long time itself.

This work presents results of quasy-continuous cell size measurements during detonation wave traveling along the circular tube. Stoichiometric C_2H_2 - *Air* and *3,5%* C_2H_2*+26,5%*O_2*+70%Ar* test mixtures were used. A contact-free self-emission method has been developed to measure instantaneous and average values of detonation cell size. The technique is based on photoelectric registration of gas luminosity in the normal direction to the wave front. Amplitude and frequency modulation of luminosity signals is caused by specific nature of combustible mixture burning related to periodic movement and interaction of transverse detonation waves. Two ways were used to extract cell size data from obtained records. The first one is the straight measurements of time interval between neighboring positive (negative) peaks of self-emission intensity, the second one is Fast Fourier Transform (FFT) analysis. Calculation of cell length was made by multiplying averaged peak-time interval by measured detonation wave velocity. Moreover, the simple smoke-foil technique has been applied to determine cell size data directly.

The experiments were performed in detonation tube having the length of *4 m* and inner diameter of *25.5 mm*. Detonation was initiated by combustion products of $C_2H_2+2{,}5O_2$ mixture formed during gas explosion in prechamber unit, *60 mm* long. Measurement zone was located near the tube end and was *805 mm* long. Detonation wave velocity was measured by two photo sensors mounted at a distance of *805 mm* from each other at the beginning and the end of measurement zone. The end of the tube was equipped with optical quartz window. The selection of directions for luminosity records and its orientation relative to tube axis were made by field diaphragm mounted directly after quartz window. To compare obtained results with smoke-foil data, two directions were located close to the inner tube wall and the third one coincided with tube axes. At some specific regimes the luminosity and smoke-foil records were made simultaneously. Spectral range for measurements was selected by slit diaphragm placed on the focal plane of inlet monochromator lens. The used optical scheme provided spatial resolution less than *2.7 mm* at the beginning of measurement zone. Luminosity signals with time resolution of up to *0.5* μs were registered by photomultipliers and recorded on digital oscilloscope interfaced with computer.

Measurements of detonation cell length dependence on initial pressure for *3,5%* C_2H_2*+26,5%*O_2*+70%Ar* were made near the wall and at the axes of detonation tube (Fig.1). The average cell length values in the studied range of initial pressure, 30 ÷ 250 mm Hg, conform well to smoke-foil data and results of (Vandermeiren and Van Tiggelen 1984).

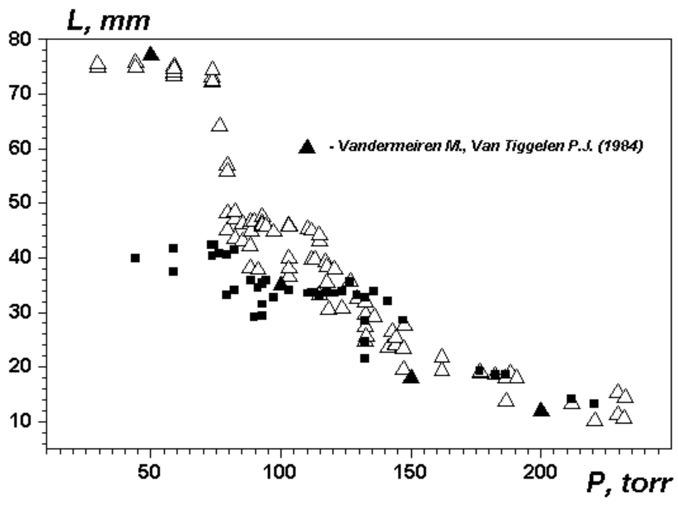

Fig.1 Detonation cell length vs. initial pressure. Mixture 3,5%C_2H_2*+26,5%*O_2*+70%Ar. Light spots - measurements near detonation tube wall; dark spots - measurements at detonation tube axes.*

It was found that cell length values at the tube axes differed from the same one near the wall, when average cell width was more than one tube diameter.

Our experiments indicated that during detonation wave movement the observed mean-square deviation of cell length could achieve of 40% from its average value even for C_2H_2 - O_2 *-Ar* mixture with a high degree of regularity (Vandermeiren and Van Tiggelen 1984). At specific initial conditions there are propagation regimes ″circular detonation tube mode″, when the rate of chemical energy release is strongly synchronized with gasdynamic structure inside detonation wave front, and the cellular structure has the best symmetry. In this

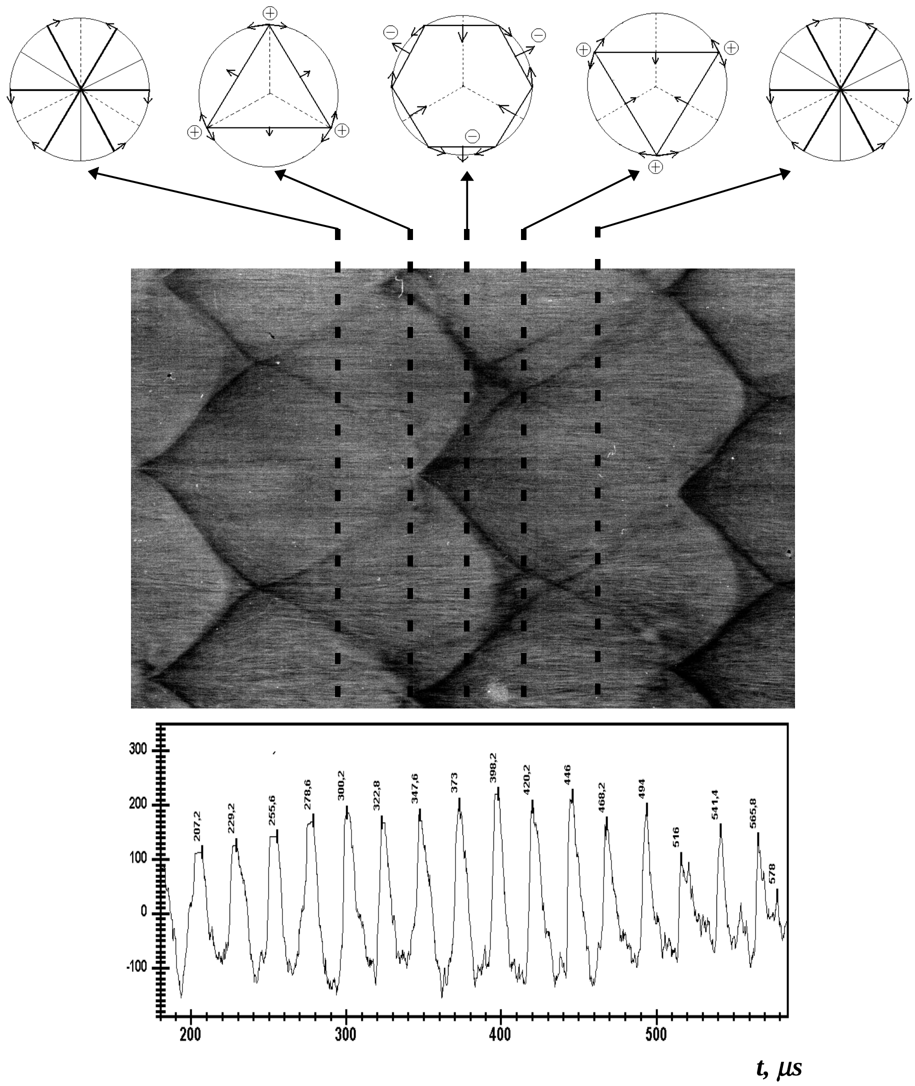

Fig.2 Smoke-foil record at detonation tube mode regime, self-emission registration and corresponding traverse wave mode scheme for N = 3

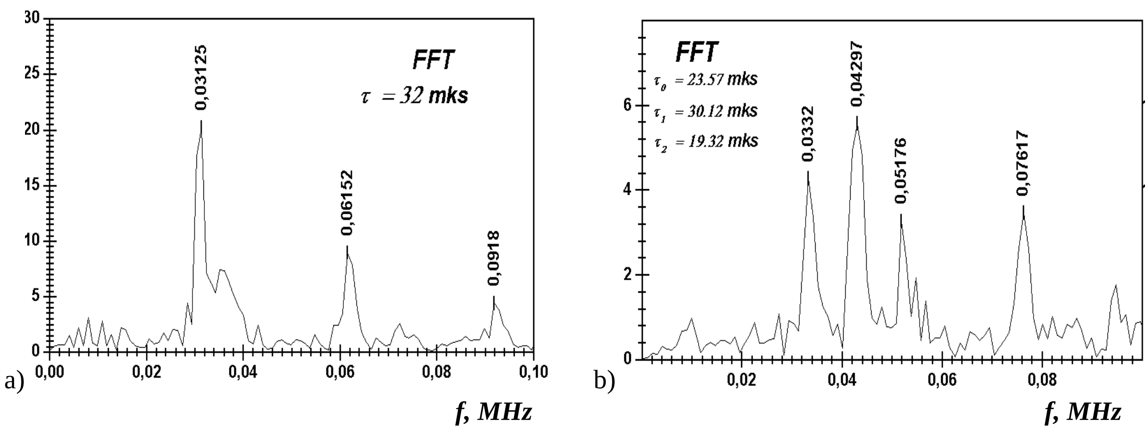

Fig.3. FFT processing of self-emission records. a-regime close to detonation tube mode N=2, P_0=117 torr; b - regime of mode mixing , P_0=127.6 torr.

case the cell width value is equal $\lambda = \pi d/N$, where *d* is the tube diameter; *N* - whole number. Large efforts have been done to obtain gas luminosity and smoke-foil records at detonation tube modes regimes. The mode schemes of traverse waves traveling for different *N* were described. Figure 2 gives the smoke-foil record and corresponding traverse wave mode schemes for *N = 3*. On a basis of schemes analysis an attempt to explain the selection criteria for mode-number N, transmission criteria $d^{*} = 13\lambda$ and longitudinal cell asymmetry for N > 2 was made. Self-emission studies of dynamic cell size properties in classically «irregular» stoichiometric C_2H_2 - *Air* mixture have shown that existence of circular detonation tube modes does not depend on mixture «regularity». Propagation regimes with mode numbers $N = 1,2$ were found.

It was established by FFT data processing that at pressure range between modes with different N the luminosity signal was superposition of several harmonics, corresponding to circular detonation tube modes. Harmonics amplitude is proportional to probability of obtaining the mode realization at any instant when detonation wave propagates. Figure 3 shows FFT's for intermediate and circular detonation tube mode regimes. It should be noted that it is one of the first experimental evidences of wave properties of gaseous detonation.

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