

# STUDIES OF ACETYLENE-OXYGEN-DILUENT DETONATIONS NEAR EXTINCTION LIMITS

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Different approaches based on experiments in finite length tubes have been suggested to determine the detonability limits [1-4] of gaseous fuels. At the same time, there is no universally accepted definition incorporating chemical properties of the mixture, pressure, temperature, and chemical composition, detonation velocity and characteristic sizes of detonation tubes.

In this work, experimental studies of the detonation structure near propagation limits have been undertaken to evolve the quantitative criterion for the limits of stable and unstable detonations. Round steel detonation tubes of inside diameters of 25.3 and 50 mm have been used in this study. Stoichiometric  $C_2H_2 - Air$  and 3.5% $C_2H_2+26.5\%O_2+70\%Ar$  mixtures at different initial pressures and ambient initial temperature has been investigated. Ion gages and pressure transducers have been used to measure detonation velocity, chemical induction time and pressure. Smoked foils have been applied for monitoring the detonation structure. The velocity evolution of reaction zones and shock fronts have been measured over 31.6-cm and 120-cm test sections of the tubes. Figure1 illustrates the positions of ion and pressure gauges along the tube with respect to the smoked foils. Velocity history and reaction zone structure of spinning wave

and decaying detonations have been investigated in details. Figure 2 shows the ranges of the flame velocity attained within the spin pitch during propagation of the spinning wave.

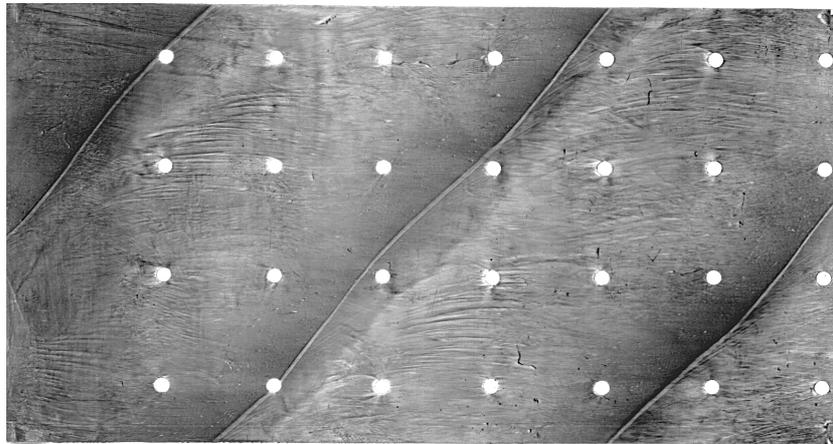


Figure 1. Soot imprint of spinning detonation propagating along the tube of 50 mm in diameter and positions of ion and pressure gauges with respect to the smoked foil.

Mixture  $3.5\%C_2H_2+26.5\%O_2+70\%Ar$ .

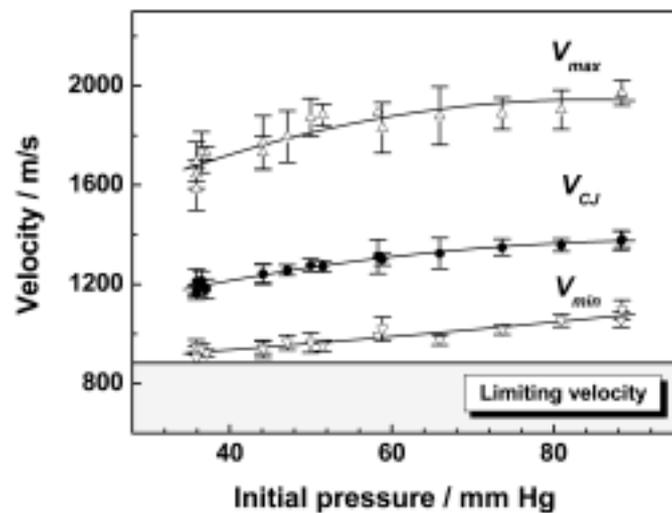


Figure 2. Ranges of flame velocity within the spin pitch of spinning detonation vs. initial pressure. Mixture  $3.5\%C_2H_2+26.5\%O_2+70\%Ar$ .

Below the pressure limit, the detonation decays. The leading shock wave decouples from the reaction front, the strong interaction between shock and flame fronts disappears. The structure of spinning wave weakens and the reaction front no more exhibits the rotary motion along the circumference of the tube. The flame acquires a characteristic “tulip” like shape,

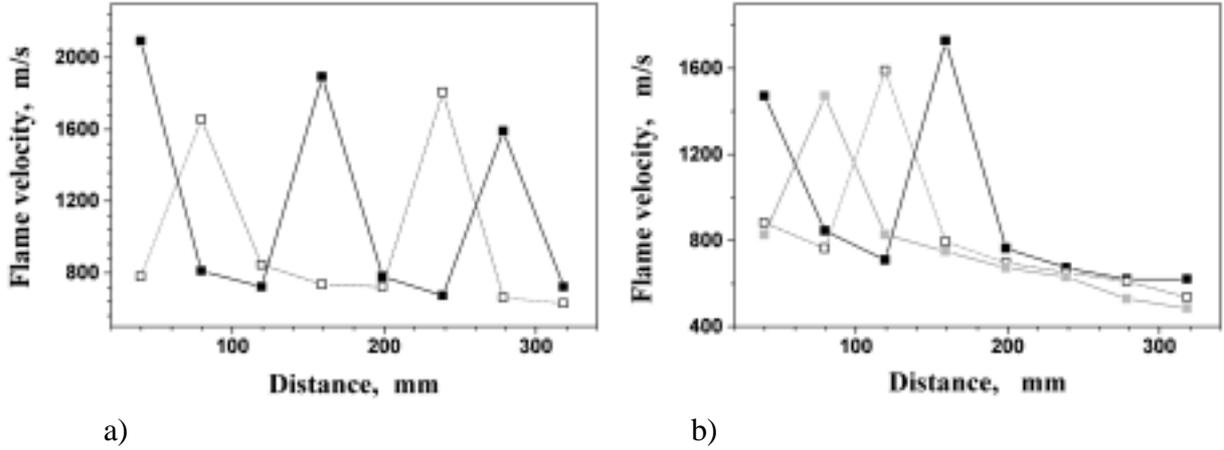


Figure 3. Typical velocity histories of the decay of spinning detonation along the test section for 3.5% $C_2H_2$ +26.5% $O_2$ +70% $Ar$  mixture at initial pressures: a –  $P_0 = 35.9$  mm Hg; b -  $P_0 = 35.3$  mm Hg. Solid and open symbols correspond to velocity measurement by two different lines of ion gauges.

followed by a period of turbulent flame propagation. Figure 3 shows typical stages of detonation destruction in the test section. As seen, the frequency of flame velocity oscillations decreases (Fig.3a) and the reaction front attains the final quasi-steady-state turbulent flame velocity (Fig.3b). Under these transient flow conditions, chemical reactivity of the mixture has been explored by reflection of the leading shock front of decaying detonation from the end flange of the tube. For different stages of the detonation destruction, the ignition delay time behind reflected shock front was measured by using the piezoelectric pressure gauge.

On the basis of results obtained, non-dimensional quantitative criteria describing the limits of stable and unstable detonations in round tubes have been suggested [5]. For stable and unstable detonations, and deflagration propagation, these empirical correlations are the following:

$$0 < Lim < 1 \quad (1)$$

$$0 < Lim < 2.5 \quad (2)$$

$$2.5 < Lim \quad (3)$$

Here,  $Lim$  is non-dimensional number  $Lim = (1.25 \tau \cdot V)/R$ ,  $\tau$  is ignition delay time corresponding to the stagnation temperature and pressure of the gas flow behind the leading shock front,  $V$  is the leading shock wave velocity and  $R$  is the radius of the tube.

These criteria link the key parameters, which are responsible for propagation of the wave near extinction limits. They provide a tool to estimate the composition and pressure ranges for stable and unstable detonations in the case of tubular confinements.

## REFERENCES

1. Manson, N., C.Brochet, J.Brossard and Y.Pujol, Vibratory phenomena and instability of self-sustained detonations in gases. Ninth Symp. (Int.) on Combustion, Academic Press, London, 1963, pp.461-469.
2. Shchelkin, K.I., Two stages of unstable combustion, Zhur. Eksptl.Teoret.Fiz., 36, 1959, pp. 600-606.
3. Kogarko, S.M., and Ya.B.Zeldovich, Detonation of gaseous mixture, Dokl.Acad.Nauk SSSR, 63, 1948, pp. 553-556.
4. Moen, I.O., M.Donato, R.Knystautas and J.H.Lee, The influence of confinement on the propagation of detonation near the detonability limits. Eighteenth Symp. (Int.) on Combustion, The Combustion Institute, Pittsburgh, PA, 1981, pp. 1615-1622.
5. Penyazkov, O.G., Near-limit conditions for propagation of detonations in round tubes, In: Advances in Confined Detonations, edited by G.D.Roy, S.M.Frolov, A.A.Borisov, Elex-KM Publishers, Moscow, 2002, pp.73-79.