

# Detonability of C<sub>2</sub>H<sub>2</sub>-O<sub>2</sub> mixtures at elevated initial temperature

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**Key words :** Detonation, Detonability, Gaseous explosive mixture, Elevated initial temperature, Cellular structure, Induction length, Global and detailed chemical kinetics, Critical diameter

The current study examines the effect of elevated initial temperature on detonation velocity, detonation cell size and critical diameter of the stoichiometric C<sub>2</sub>H<sub>2</sub>+2.5O<sub>2</sub> and C<sub>2</sub>H<sub>2</sub>+2.5O<sub>2</sub>+3,5Ar mixtures and the lean mixture C<sub>2</sub>H<sub>2</sub>+10O<sub>2</sub> (equivalence ratio  $\phi=0.25$ ).

## Experimental Method

The experiments were conducted with the set-up displayed in Fig.1. The test vessel consists of a 7.2 m long and 53 mm inner diameter tube made of 304 L stainless steel. The tube is supplied with a low-voltage, high-intensity electrical power source (18.6 V-DC, 1700A) and heated by Joule effect to temperature as high as 900K, at a rate of about 100K per minute. The main tube is connected to a tube of the same diameter and 0.5 m long. This tube, filled with a very detonable mixture, works as a shock driver to initiate the detonation of the mixture in the main tube. Detonation velocity in the studied mixture is measured all along its propagation using a hyperfrequency Doppler interferometer. The electromagnetic beam (X Band, wavelength 3.469 cm) introduced through a plexiglas window located at the end of the detonation tube is partly reflected by the detonation front. Detonation cellular structure is recorded by the classical smoked foil technique.

At elevated initial temperature, great care has been taken to assess the initial composition of the gaseous mixtures because of the risk of catalytic effects due to the nature of the detonation tube. So, chromatography analysis of gaseous samples have been made with respect to temperature, pressure and residence time inside the detonation tube. The maximum working initial temperature has been determined according to these results.

## Results and Discussion

We have studied the detonation of the three mixtures in the range of initial pressure  $P_0=0.05$ -1bar at two initial temperatures  $T_0=293$  and 500K (maximum working temperature).

Self-sustained detonation velocity measurements are in good agreement with C.J. calculations (Fig. 2).

Typical smoked foil records of the cellular structure of self-sustained detonations for ambient and elevated initial temperature ( $T_0= 293$  and 500K) are displayed in Fig. 3. As a general remark we can say that cell regularity increases with initial temperature.

Fig. 4 shows that the cell size  $\lambda$  varies with the initial temperature  $T_0$  and pressure  $P_0$  according to the following relationship :

$$\lambda \sim P_0^{-n} T_0^m \quad (1)$$

Experimental values of  $n$  and  $m$  for both mixtures are displayed in table 1. About  $P_0$  dependence, the coefficient  $n$  remains nearly constant and equal to 1.1-1.2. About  $T_0$  dependence, two different trends are observed. As  $m \approx 0.9$  in the case of the stoichiometric mixtures  $\lambda$  increases with  $T_0$ . For the lean mixture,  $\lambda$  is nearly independent of  $T_0$  since  $m \approx 0$ .

An explanation of the  $\lambda(P_0, T_0)$  evolution is provided for both cases assuming (i) that  $\lambda \sim k L_i$  and (ii) that  $L_i$  can be calculated through the ZND model with either global or detailed chemical kinetics. Using global kinetics law for C<sub>2</sub>H<sub>2</sub> based mixtures  $L_i$  can be approximated by the following relationship :

$$L_i \cong [\rho_0]^{-1} \exp \frac{Ea}{RT_{ZND}} \quad (2)$$

where  $Ea=25$  kcal/mol is the global activation energy,  $\rho_0$  the initial density and  $T_{ZND}$  the post-shock temperature. Calculations of  $(k L_i)$  with global kinetics (Fig.4) are in agreement with experimental data. This kind of comparison is less satisfactory in the case of detailed kinetics (Fig.5) (a better agreement is obtained with the stoichiometric mixtures). These results can also be represented by the relationship  $k L_i \cong P_0^{-n} T_0^m$  and corresponding calculated values of  $n$  and  $m$  (table 1) are close to the experimental ones.

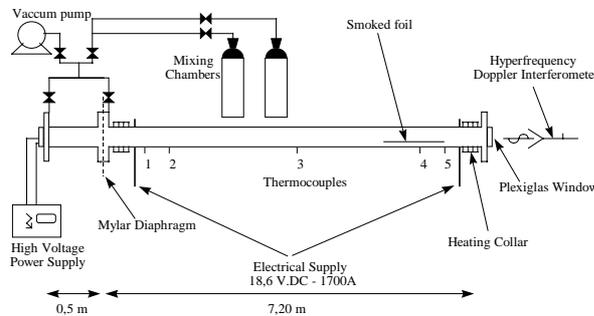
Explanations of these results are the following :

- coefficient  $n$  : the variation of  $T_{ZND}$  with  $P_0$  is small (especially when  $T_{ZND}$  is low) and so does the exponential term in Eq (2). This does not influence the variation of the preexponential term so that the coefficient  $n$  is nearly constant whatever the mixtures and the value of  $Ea/RT_{ZND}$ .

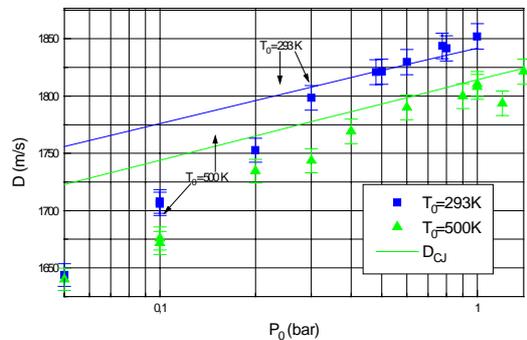
- coefficient  $m$  : the variation of  $T_{ZND}$  with  $T_0$  is more important than with  $P_0$  (especially when  $T_{ZND}$  is low). The weight of the exponential term on  $L_i$  variations is small if  $Ea/RT_{ZND}$  is low ( $\sim 5$ ) but becomes large with high values of  $Ea/RT_{ZND}$ .

About the variation of thermodynamical ZND characteristics, the above trends are quite general and explain that the variation of  $m$  is much larger than that of  $n$ .

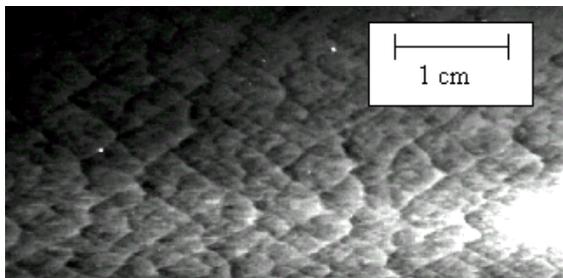
In order to establish at elevated temperature a link between cell size behaviour with one of the dynamic parameters of a detonation, as for example the critical tube diameter  $d_C$  of its transmission from a tube into a large volume, we have performed a few experiments with the stoichiometric mixtures. Results indicate that the classical relationship  $d_C=13\lambda_{CJ}$  holds. As a consequence, because of increasing  $\lambda$  with  $T_0$ , detonability of mixtures with low  $Ea/RT_{ZND}$  drops at elevated temperature.



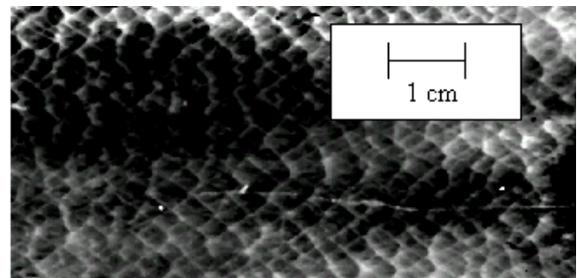
**Figure 1 :** The EHD set-up



**Figure 2 :** Detonation velocity vs initial pressure for  $C_2H_2+10 O_2$  mixture at two initial temperatures

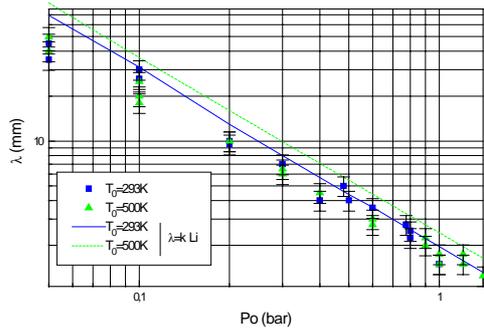


a)  $T_0=293K P_0=0.8bar$

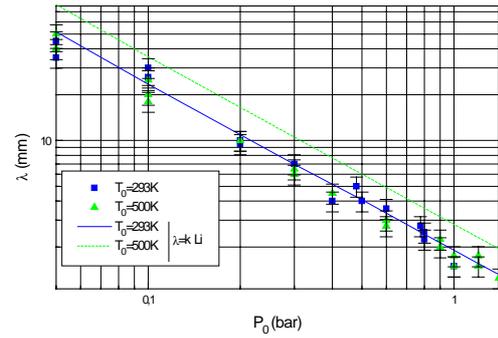


b)  $T_0=500K P_0=0.6bar$

**Figure 3 :** Smoked foil record of detonation in the  $C_2H_2+10 O_2$  mixture



**Figure 4 :** Detonation cell size vs initial pressure for  $C_2H_2+10 O_2$  mixture at two initial temperatures. Lines correspond to  $\lambda=k L_i$  calculations with a global kinetics laws.



**Figure 4 :** Detonation cell size vs initial pressure for  $C_2H_2+10 O_2$  mixture at two initial temperatures. Lines correspond to  $\lambda=k L_i$  calculations with a detailed kinetics laws.

mixtures	Experimental		Global kinetics		Detailed kinetics	
	n	m	n	m	n	m
$C_2H_2+2.5O_2$	1.25	0.9	1.2	0.8	1.1	0.9
$C_2H_2+2.5O_2+3.5Ar$	1.3	0.85	1.2	0.9	1.1	0.9
$C_2H_2+10 O_2$	1.15	-0.1	1.2	0.4	1.1	0.7

**Table 1 :** Experimental and calculated values of n and m