

Influence of Suspension Generation on Dust Explosion Parameters.

Olivier Bozier, Bernard Veyssi re.

Laboratoire de Combustion et de D tonique, ENSMA, Poitiers, France

Corresponding Author, Olivier Bozier: bozier@lcd.ensma.fr

Introduction

Mechanism of flame propagation in dust-air mixtures is still not well understood in comparison with the case of premixed gaseous mixtures. This is mainly due to the lack of experimental data on account of the difficulties to perform experiments in well-controlled and reproducible conditions. Indeed, under normal gravity conditions, dust particles fall down on the vessel walls. To correct this effect, dispersion is often achieved in a turbulent flow, which generates important gradients of particles concentration and scattering of initial conditions. Until now, only a limited number of experimental works has tried to elucidate the influence of initial conditions on the characteristics of explosion in a closed vessel.

The objective of present work is to obtain a better knowledge of the initial state of the mixture at the moment of ignition and try to correlate it with the combustion characteristics at constant volume.

Experimental Details

Two vessels have been specially designed for this study. The first one mainly consists of a completely transparent cylindrical chamber with an octagonal cross section and a small length-to-diameter ratio (volume 20 l, $L = 500$ mm, $D = 230$ mm and $L/D \approx 2,2$), it allows visualization of the dispersion process in all directions. The second one, has geometrical characteristics similar to those described above, is made of steel and can support 50 bar overpressures, which allows to measure the characteristics of combustion at constant volume. The dispersion system consist of 2 linear perforated pipes equipped with a deflector connected to a pressurized air auxiliary tank, diametrically opposed in the vessel. Particle dispersion in the chamber is achieved by means of the turbulent flow created by the discharge of the pressurized air. The apparatus (with transparent walls) is shown in Fig. 1.

Experiments were made with cornstarch particles dispersed in air with average mass concentrations up to 400 g/m^3 .

PIV and LDV are used to determine the aerodynamic characteristics of the flow field during the dispersion process, and high-speed video-imaging to observe the evolution of dust distribution inside the chamber. The use of PIV in these conditions (two-phase mixture, unsteady flow) is expected to allow drawing up 2D instantaneous maps of velocity fields and turbulence level in different plans of the chamber, thus providing more accurate data on the initial state of the mixture at ignition time.

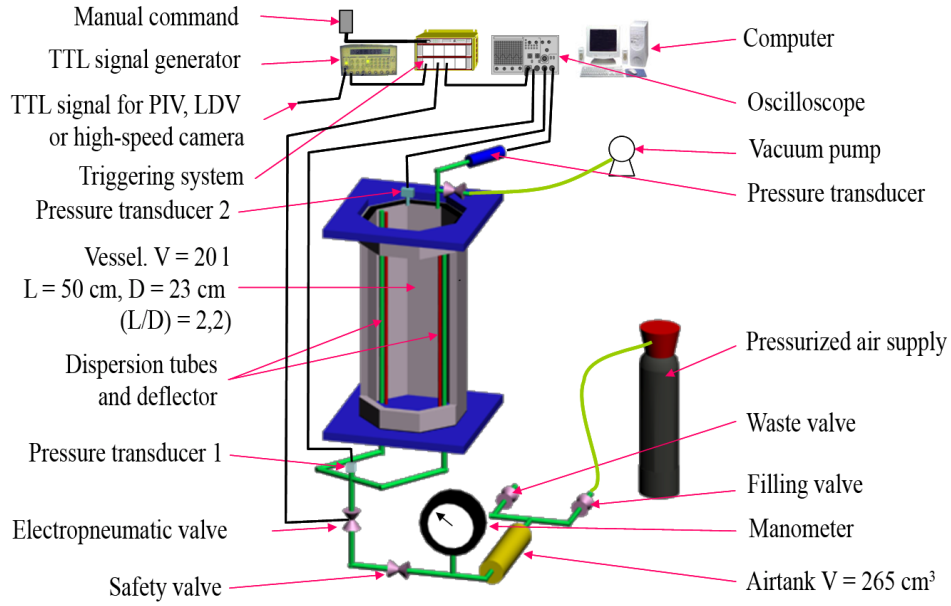


Figure 1. Experimental apparatus.

Results

a) Mixture characteristics at ignition.

Time evolution of velocities fields and turbulent structures are examined (example in Fig. 2 and 3). Velocity and turbulence intensity reach their maximum (of the order of magnitude of 20 m/s in the middle of jet) about 30 ms after the beginning of dispersion. They stabilize rapidly and beyond 500 ms, their values remain quasi-constant in the vessel (absolute value less than 50 cm/s). Large structures appear at 100 ms and their diameters increase from 6 cm to 16-20 cm (size of the vessel) at about 700 ms.

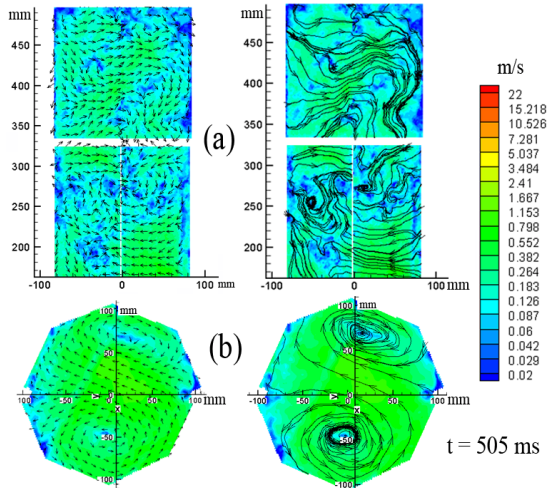


Figure 2. Velocity fields and streamlines obtained by PIV at $t = 505$ ms after the beginning of dispersion process.

- a) in a vertical plane.
- b) in a horizontal plane.

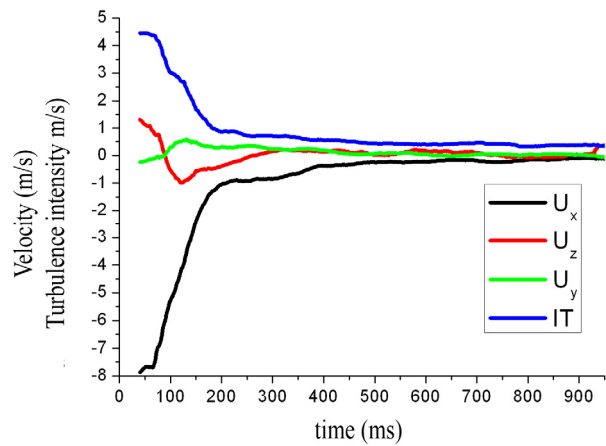


Figure 3. Evolution of velocity and turbulence intensity at the point located in the horizontal symmetry plane of the vessel and at equal distance between the center of the vessel and the deflector.

Characteristic dispersion times and distribution of particle are examined (example Fig. 4). Between 400 and 800 ms, particles seems to become well distributed in the chamber.

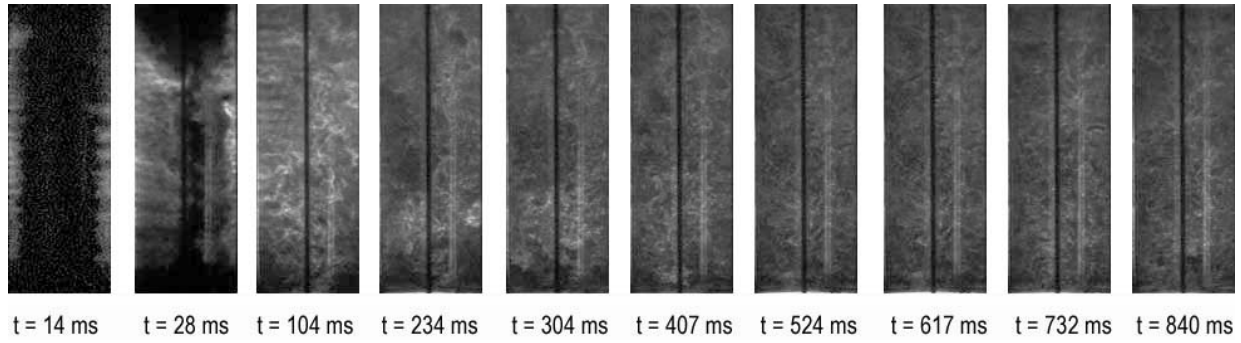


Figure 4. Sequence of dust dispersion recorded by high-speed video (1125 fps) coupled with laser tomography.

Thus, we can define in this range a delay before ignition, for which the mixture is likely homogeneous, with minimal velocities and turbulence intensity.

b) Explosion parameters

In Fig. 5 are plotted the evolution of maximum explosion pressure, $P_{\max}$ and the maximum rate of pressure rise, $(dP/dt)_{\max}$, as function of the turbulent intensity measured in the center of the vessel. Evolution of burning velocity, $S_{c\tau\max}$ (determined at $(dP/dt)_{\max}$) as function of the turbulent intensity is plotted in Fig. 6 and compared with values obtain by Tai et al. (1998) and Pu et al. (1990). By extrapolation at infinite value of the delay before ignition, we define a hypothetic steady state mixture indicated in Fig. 5 and 6 by points located at a turbulent intensity equal to zero. $P_{\max}$, $(dP/dt)_{\max}$ and $S_{c\tau\max}$ determined from our experiments increase with turbulent intensity as expected. Values measured for stoichiometric dust-air mixture are in satisfactory agreement with results obtained by other researchers (see Table. 1).

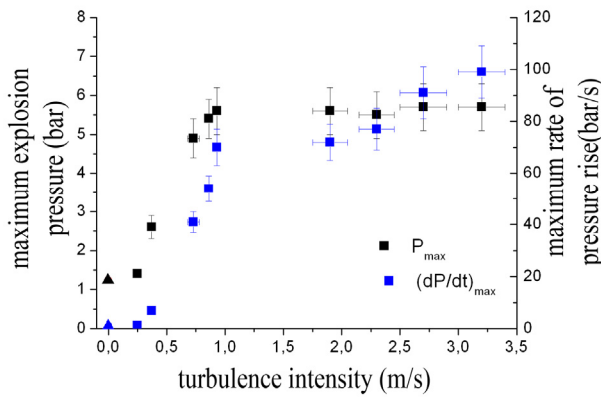


Figure 5. Variation of maximum explosion pressure $P_{\max}$ and maximum rate of pressure rise $(dP/dt)_{\max}$ with turbulent intensity. Equivalence ratio 1.

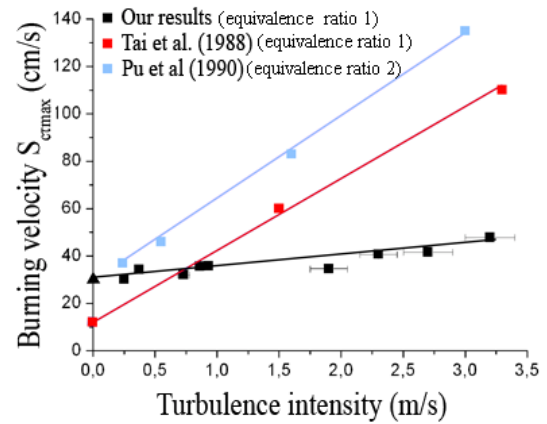


Figure 6. Variation of burning velocity $S_{c\tau\max}$ with turbulent intensity.

Table 1. Maximum explosion pressure, $P_{\max}$, Maximum rate of pressure rise, $(dP/dt)_{\max}$, Burning velocity, $S_{ct\max}$, at $(dP/dt)_{\max}$, and Coefficient K_{St} . Stoichiometric dust-air mixture.

	Our results	Bond et al. (1985)	Lemos et al. (1989)	Nagy et al. (1985)	Pu et al. (1990)	Theoretical (*)
Volume (l)	20	333	20	12,3	25	
$P_{\max}$ (bar)	1,2 – 5,7	6	7,8	6	5,5	11,4
$S_{ct\max}$ (cm/s)	16 – 48		5,8			
$(dP/dt)_{\max}$ (bar/s)	1 – 100	22	30	150	15	
K_{St} (bar.m/s)	0,1 – 27	15	12	35	4	

(*)Calculated with thermodynamic code Quartet (Heuzé 1992)

Conclusions

Experimental study (with PIV, LDV, high-speed video imaging) of the flowfield in the chamber and of the distribution of dust suspension has allowed to define better controlled conditions at the instant of mixture ignition. Between 500 and 700 ms after the beginning of the dispersion process, the suspension is quite well distributed and the turbulence has sufficiently decayed. Explosion parameters measured in these conditions decrease with turbulence intensity and are in satisfactory agreement with those determined by other authors.

Acknowledgments

This work was supported by CNES, INERIS and Region Poitou-Charentes.

References

- Bond J.F. 1985 *The influence of turbulence on dust and gas explosions in closed vessels*, M. Eng. Thesis, McGill University, Canada.
- Heuzé O. 1992 *Quartet: Code de calcul thermochimique pour obtenir les propriétés thermodynamiques des produits de combustion et de détonation*.
- Lemos L.E.P.T. 1989 *Contribution à l'étude des mécanismes de propagation des flammes dans les mélanges hétérogènes gaz-particules solides. Cas des mélanges amidon-air* Thèse de Docteur de l'Université de Poitiers ENSMA Poitiers France.
- Nagy J; & Verakis C. 1985 *Development and Control of dust explosions* Marcel Dekker Inc. New-York.
- Pu Y.K., Jarosinski J., Johnson V.G. & Kauffman C.W. 1990 *Turbulence effect on dust explosions in the 20-liter spherical vessel*, 23rd Int. Symp. on Comb.: 843-849.
- Tai C.S., Kauffman C.W., Sichel M. & Nicholls J.A. 1988 *Turbulent dust combustion in a jet stirred reactor* AIAA Progress in Astronautics and Aeronautics 113 : 62-86.