VISUALISATION OF DUST EXPLOSION UNDER MICROGRAVITY CONDITIONS

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INTRODUCTION

The physical mechanism of flame propagation in dust-air mixture is still not well understood in comparison with a similar mechanism related to homogeneous gas flames. For dust-air mixtures it is difficult to determine such fundamental quantities as laminar burning velocity, flame thickness, quenching distance, etc. This is due to experimental difficulties in the generation of a uniform, quiescent laminar dust suspension with reproducible concentration. Another problem is the influence of normal gravity. As a consequence, the experimental results are not reliable and are usually apparatus dependent.

Laminar dust flames in comparison with laminar gas flames are a function of a much greater number of parameters. They depend not only on dust concentration and conditions of heat transfer, but also on the size of the particles and the content of volatiles and moisture in the substance. The following phenomena play an important role in dust combustion: dust concentration, uniformity of the dust suspension, dust sedimentation in the gravity field and type of the ignition system.

Dust-air mixture can be produced by means of turbulent mixing [1], fluidized bed technique [2], dust feed assembly [3], acoustic field [4], or electrical field [5]. All these methods have visible effects on the combustion process.

Most of the ground-based experiments on dust combustion are carried out in the constant volume vessels with pneumatic dispersion systems, where turbulent mixing creates a dust-air mixture. It was decided to use such a system in the present experiments.

The objective of the present work is to report an experimental comparative study on the effect of turbulence and ignition system on dust combustion in the constant volume vessel, provided both in ground conditions and in microgravity environment created by a falling assembly in the drop-tower.

EXPERIMENTAL DETAILS

The experiments were conducted in a 8.4 liter cylindrical closed combustion tube of 0.172 m inner diameter and 0.36 m length (L/D=2.1), made of organic glass (Fig. 1).

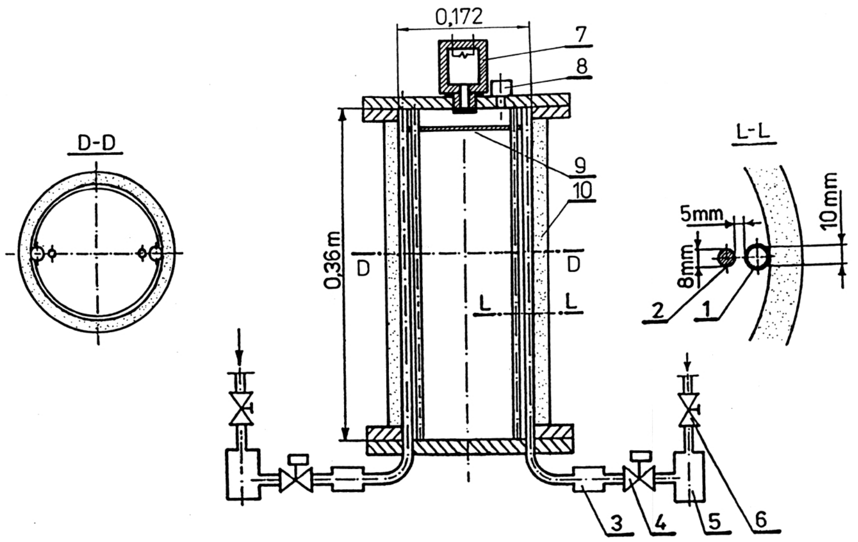

Fig. 1. Structure of 8.4 l testing vessel (1-dispersion tube; 2-bar; 3- dust vessel; 4-magnetic valve; 5-air reservoir; 6-mechanical valve; 7-ignitor; 8-pressure transducer; 9-disc; 10-transparent wall).

The dispersion system, characterized by a small scale of turbulence was used [1]. The duration of the dispersion process was about 100 ms and the mixture introduced caused pressure in the vessel to increase. A gas igniter with energy of 0.2 kJ was used. It ignited the dust-air mixture by a stream of combustion gases flowing from the igniter reservoir. The stream could ignite the dust mixture in the central part of the vessel (volume ignition) or in top part of it (surface ignition - the stream flowed over the surface of a disc located perpendicular to the jet flow, not far from the igniter). The pressure history was measured by transducer FTSV 2100 and sampled and recorded by an AD card installed in a PC computer.

Cornstarch ($C_6H_{10}O_5$) was used as a fuel. The particles was almost spherical with the mean diameter of 14μm. Volume distribution of the particles as a size function is shown in Figs. 2 and 3. Particles smaller than 10μm occupy 30% of the volume and with diameter between 10-20μm 50%. The remaining 20% of the volume is occupied by particles with diameter between 20μm and 50μm.

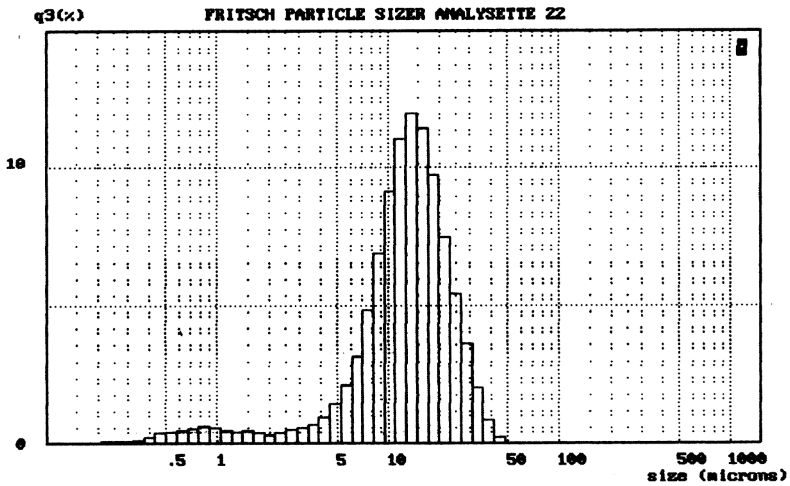

Fig. 2. Volume distribution of cornstarch particles.

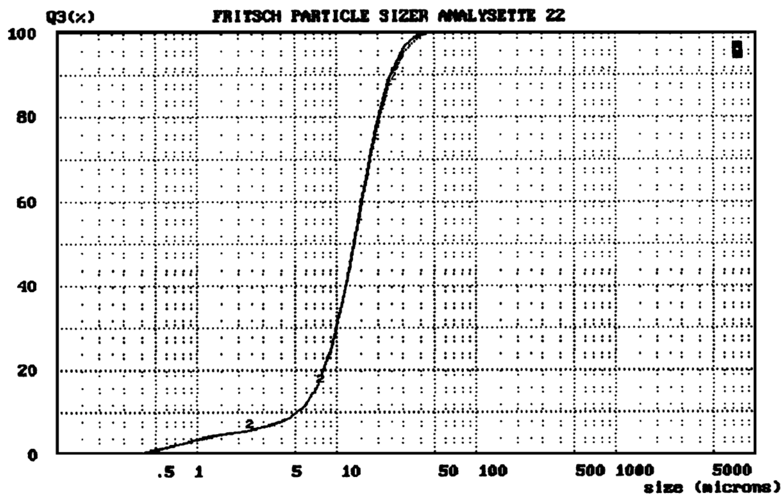

Fig. 3. Integral curve of the cornstarch particle volume distribution.

Microgravity experiments were conducted in the Institute of Heat Technology and Refrigeration of the Technical University of Lodz, in a drop tower, which could provide 10^{-2} g conditions for 1.2 seconds.

RESULTS AND DISCUSSION

The measurements of RMS turbulent velocity u' and instantaneous mean velocity U as a function of time are shown in Fig. 4.

The velocities of dispersion-induced turbulence reach their maximum values roughly at 30 ms. The maximum value of RMS velocity is as high as 9 m/s. Turbulence decays very fast and at 400 ms the value of the RMS velocity is less than 0.3 m/s.

It was found before [1] that dust suspension was almost steady state under microgravity conditions. This makes it possible to study dust explosion under stationary dust suspension, practically without any influence of turbulence.

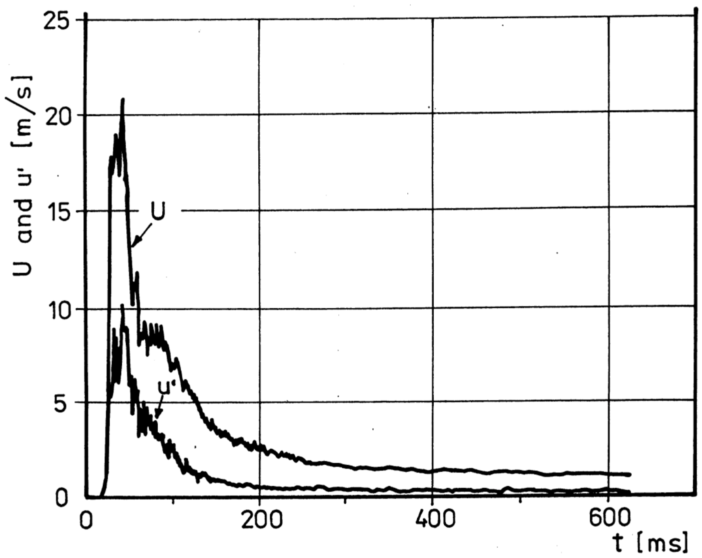

Fig. 4. The ensemble average instantaneous velocity U and RMS velocity u` as a function of time t in the closed vessel.

The delay time 500 ms was used in the experiments to eliminate the effect of turbulence level on the development of combustion process.

The pressure-time history for the constant volume combustion of cornstarch dust-air is shown in Fig. 5. The experiments were carried out under normal gravity and microgravity conditions.

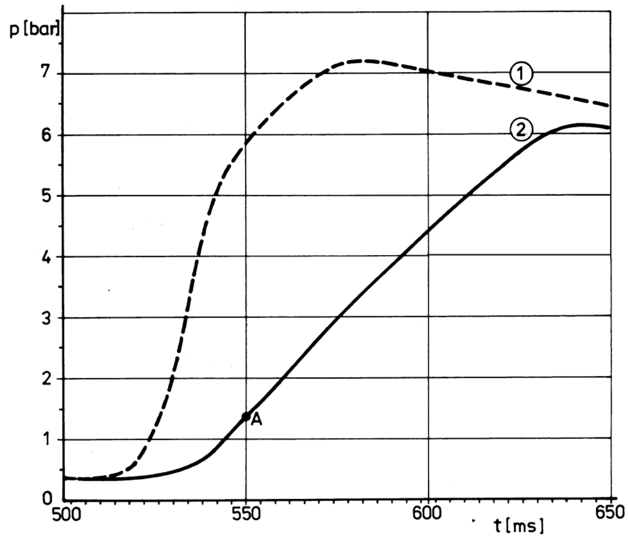

Fig. 5. Variation of explosion pressure as a function of time. Ignition delay time 500 ms. Microgravity conditions (1-ignition in the center of the vessel-; 2-ignition at the edge of the disk located in the upper part of the vessel; A-at this point the flame front passed the distance from the top to the bottom of the vessel).

The curves obtained under the normal gravity conditions in comparison with the microgravity curves decrease in their peak values and in the rate of pressure rise due to gravity sedimentation.

The visualization of dust combustion in the closed vessel under microgravity conditions showed, for ignition delay time 500 ms, a very irregular flame front and irregular distribution of the regions with local reactions at a later stage of combustion (Fig.6). The continuous flame front has never been observed. It is evident from these experiments, that the dispersion system selected with great care does not secure a uniform distribution of dust in the dust-air mixture.

The mixture ignited by a stream of hot gases flowing along the axis burns faster than that ignited in the upper part of the vessel. The maximum pressure is also higher for central ignition.

The irregular mixture composition in the vessel does not change much during combustion - bright regions representing fast reactions are quiescent.

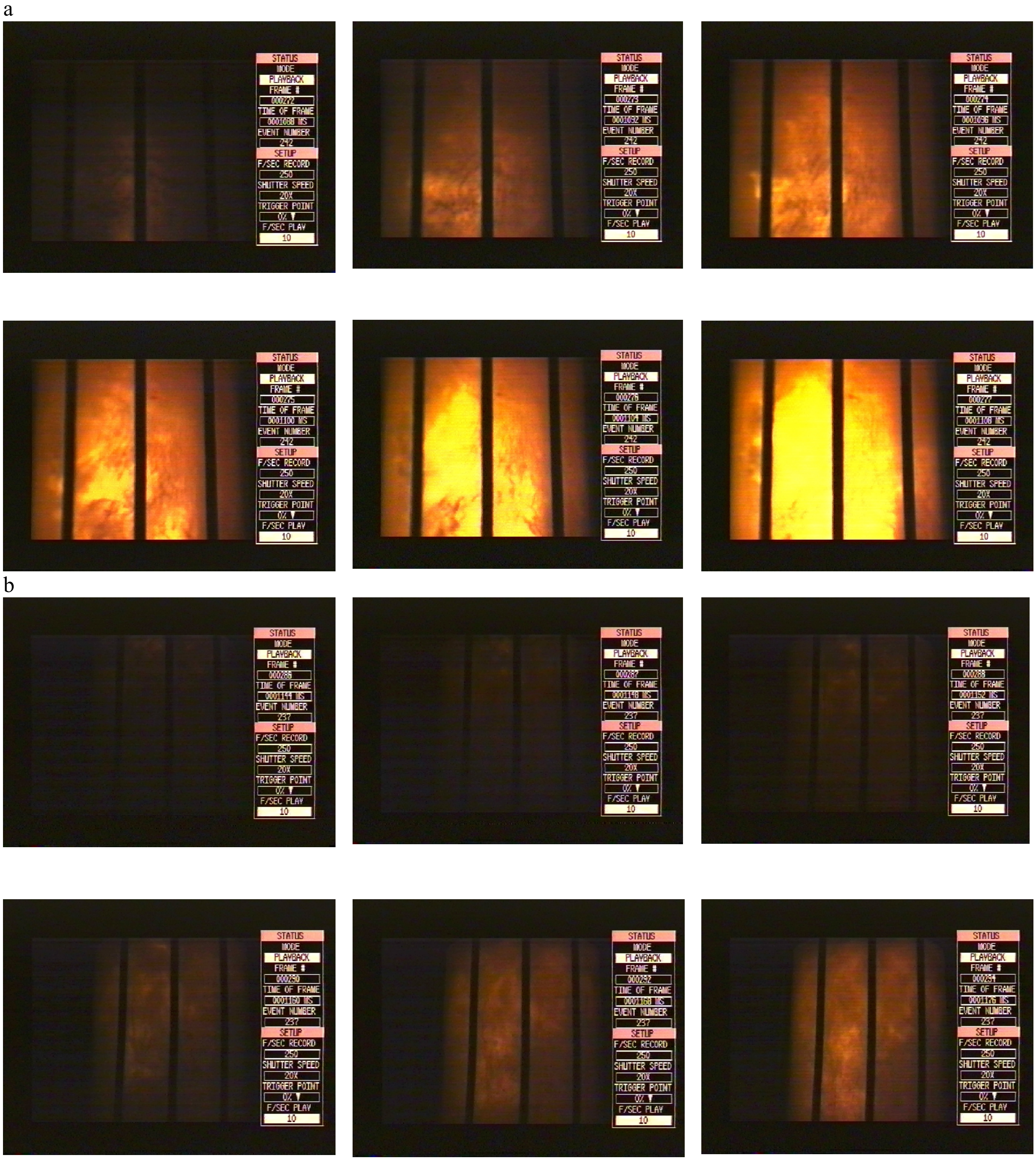

Fig. 6. History of flame propagation and combustion. Framing rate: 250 frames/s. (a- center ignition; b- top ignition)

During flame propagation from the top to the bottom of the vessel only small part of heat is released (point A in Fig. 5), the other parts being released far behind the flame front.

At the final stage of combustion the hot regions generate turbulent motion.

ACKNOWLEDGEMENTS

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