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Influence of the size distribution and concentration on wood dust explosion: Experiments and reaction modelling

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Abstract

The explosion ability of wood dust was characterized by a 20 L explosion sphere (Kühner). The overpressure inside the sphere is recorded during the explosion. The results show that the violence of the explosion is all the more important that the particle size is low. A model based on balances on chemical reaction, kinetics and thermodynamics leads to the representation of the pressure change during the explosion. There is a good agreement between the calculations and the experiments.

Keywords: Explosion; Dust; Overpressure; Combustion

1. Introduction

A lot of combustible powders can cause explosion when they are mixed with an oxidant like O_2 and if the mixture is ignited with an energy source (electrical discharge for example). We can find these powders in the food-processing industry (flour, sugar, etc.), in the mechanical engineering industries (Aluminium, etc.) and in the chemical engineering industries (fertilizer, plastic, pulverulent waste, etc.).

One explosion per day occurs on average in France [1]. The reasons are the increase of storage capacity and of handling flows of powders which present lower and lower sizes [2]. The hazard is then linked to the transport and the storage of pulverulent materials.

Only the knowledge of the parameters which quantify the explosion ability of powders and the control of their environment can help the risk prevention.

Cashdollar [3] said that the form and the size of powders have a strong influence on their explosion. As a matter of fact these physical parameters are linked to the particles volumic surface which plays a role in the combustion kinetics. Moreover large size particles (>500 μm) do not significantly participate in the flame propagation because of the sedimentation. The fine fraction of the size distribution controls then the explosion due to its large volumic surface and its ability to stay in suspension. These conclusions were supported with experimental results on aluminium and coal powders [4]. In each case maximum overpressure and maximum rate of pressure rise decrease when the particle size increases. This result was also observed by Soundararajan and al. [5] on ferrous materials.

Authors also present results of explosion tests of mixed powders of different sizes which lead to the inhibition of the explosion mechanism. One condition is that one of the two powders is inert and the other is combustible [6,7]. These works show that the lower the inert particle size is, the lower is the amount of these particles necessary to prevent the explosion.

Finally Sweiss and Sinclair [8] measured the maximum admissible O_2 concentration to prevent dust explosion as a function of particle size. They obtained the following result: the lower the particle size, the lower the maximum admissible O_2 concentration.

The aim of the present work is first to characterize experimentally the explosion of wood dust of different

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sizes. Secondly a descriptive model for the increase of the pressure during the explosion is presented. The calculated values are finally compared with the experiments. We will focus on the effects of powder concentration and size in the model and then on the explosion mechanism.

2. Experimental study of the dust explosion

2.1. Physical properties of wood dust

Tested wood dusts are produced by sanding a mixture of beech and oak.

Particle density equals 1600 kg/m^3.

The large size distribution of the wood dust allows the preparation of four size fractions by sifting (Alpine). The mean volumic diameter was determined for each fraction by Coulter counter. The values obtained are presented in Table 1.

2.2. The 20 L explosion sphere

The 20 L explosion sphere was initially developped by Siwek [9] in order to characterize the ability of powders to explode. The parameters measured are the maximum pressure P_{max} and the maximum rate of pressure rise in the sphere, $(dP/dt)_{max}$ (Fig. 1).

The test bench is composed of a spherical chamber of 20 L in stainless steel (Fig. 2).

A cooling system based on cold water circulating in a double jacket disperses a part of the heat of the exothermic reaction. The overpressure inside the sphere is measured by two piezoelectric manometers. The values are recorded by a computer (system KSEP 310 and KSEP 332, Kühner).

The volume of the dust container equals 0.6 L. It is connected to the spherical chamber by an electric valve.

The container is first pressurized to 20 bars before the valve opens. Powder is then discharged in the sphere through a dispersion plate.

The explosion is caused by two chemical ignitors which are placed in the sphere and release a total energy of 10 kJ.

2.3. Tests description

For each sample corresponding to each size fraction of the wood dust explosions are carried out with different

Table 1
Mean volumic diameter for each fraction of the wood dust

Size fraction	25–45 μm	45–71 μm	71–90 μm	90–125 μm	Raw wood
d_v (μm)	23.5	42.7	62.5	82.5	36

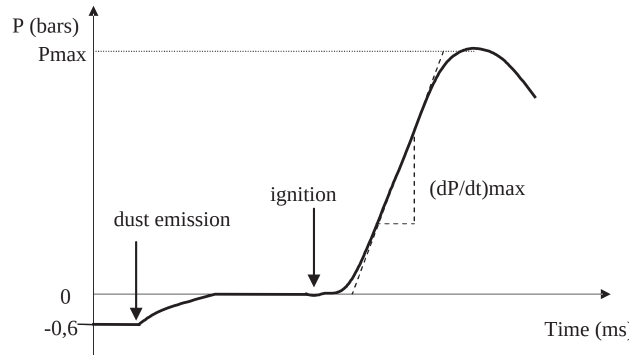

Fig. 1. Evolution of the overpressure in the sphere during the explosion.

masses of powder dispersed in the sphere (2.6 g to 40.9 g). An experimental difficulty is the control of the moisture of the powder which strongly influences the combustion. For each sample the humidity equaled 40% except for the fraction 71–90 μm (humidity = 60%). The results obtained with this fraction are therefore not presented. Finally to estimate the effect of the explosion without the energetic contribution of the chemical ignitors blank tests were made without powder.

3. Results

Fig. 3 shows the pressure evolution inside the sphere during the 25–45 μm particles explosion. The amount of powder which reacts varies between 2.6 and 40.9 g.

Tests show that a maximum overpressure and a maximum rate of pressure rise exist as a function of dust concentration. This concentration corresponds to a mass of 14.6 g in the 20 L of the sphere. The maximum values obtained are P_{max} = 7.7 bars (±0.5 bars) and $(dP/dt)_{max}$ =

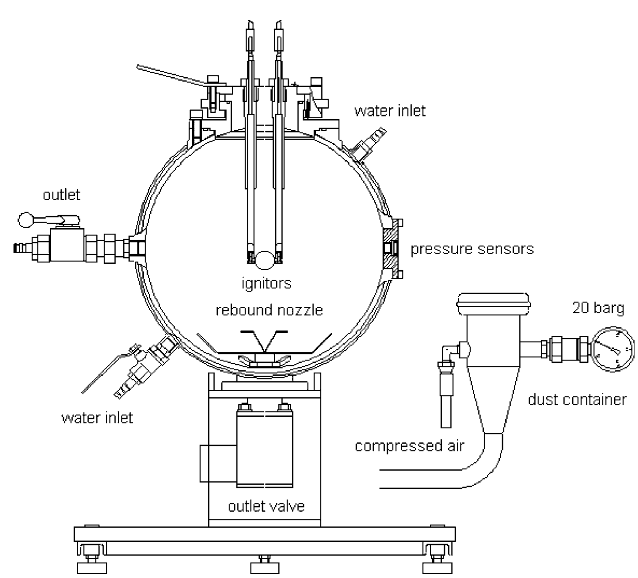

Fig. 2. The 20 L explosion sphere.