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STUDY OF EXPLOSION CHARACTERISTICS OF WOOD DUST CLOUDS IN DEPENDENCE OF THE PARTICLE SIZE DISTRIBUTION

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Abstract

The article deals with the measurement of explosion characteristics of wood dust. The measurements were carried out according to STN EN 14034-1+A1:2011 Determination of explosion characteristics of dust clouds. Part 1: Determination of the maximum explosion pressure p_{max} of dust clouds and the maximum rate of explosion pressure rise according to STN EN 14034-2+A1:2012 Determination of explosion characteristics of dust clouds - Part 2: Determination of the maximum rate of explosion pressure rise $(dp/dt)_{max}$ of dust clouds. On the basis of measurements, we found that the distribution of the particles has a significant impact on the parameters of wood dust samples.

Key words

wood dust clouds, explosion characteristics, maximum explosion pressure, maximum rate of explosion pressure rise, lower explosion limit.

INTRODUCTION

Dust explosions have accounted for numerous deaths, disappearance of companies, and large financial losses, and yet they are one of the least recognized of industrial fire hazards. They can occur within any process where a combustible dust is handled, produced or stored, and can be triggered by any energy source, including static sparks, friction and incandescent material (1).

A dust explosion can occur when particulate solid material is suspended in air and a sufficiently energetic ignition source is present. The consequences are often similar to those arising from a gas explosion in terms of impact on people, physical assets and business production. While most industrial practitioners are familiar with at least the basic concepts of gas explosions (e.g., the need for a fuel, oxidant and ignition source), the same cannot be said about dust explosions. The primary distinguishing factor of the dust and gas explosions is the phase of the fuel itself—solid versus gaseous. Particle size is therefore a dominant issue in the efforts aimed at preventing dust explosions and mitigating their consequences. The National Fire Protection Association (NFPA) defines dust as any finely divided solid, 420 mm or 0.017 in. or less in diameter (i.e., the material capable of passing through the U.S. No. 40 Standard Sieve).1 Since the range of explosive particle sizes for a given material can be quite large, this definition highlights the importance of considering the particle size distribution in addition to a mean or median particle diameter. Further, the shape for which a given material poses a dust explosion hazard may not be limited to spherical or near-spherical particles, but could include flakes, fibres and flocculent forms (2).

Properties of dust clouds and settled dust are characterized by the Lower Explosive Limit (LEL), maximum explosion characteristics (maximum explosion pressure p_{max}, maximum rate of explosion pressure rise $(dp/dt)_{max}$), minimum *ignition* energy E_{min}, minimum ignition temperature of dust clouds t_{roz}, induction period for ignition τ_i and the Limiting oxygen concentration (LOC) (3).

The article presents practical measurement of the maximum explosion pressure and the maximum rate of explosion pressure rise of wood dust clouds. The measurements were carried out in accordance with STN EN 14034-1+A1:2011 Determination of explosion characteristics of dust clouds. Part 1: Determination of the maximum explosion pressure p_{max} of dust clouds and the maximum rate of explosion pressure rise according to STN EN 14034-2+A1:2012 Determination of explosion characteristics of dust clouds - Part 2: Determination of the maximum rate of explosion pressure rise $(dp/dt)_{max}$ of dust clouds (4).

Elimination/control of dust cloud explosion hazards requires:

- Understanding of the explosion characteristics of the dust(s),
- Identification of locations where combustible dust cloud atmospheres are or could be present during normal and abnormal operating conditions,
- Identification of potential ignition sources that could be present under normal and abnormal conditions,
- Taking measures to eliminate and/or minimize the occurrence of dust explosions and protect people and facilities against their consequences (5).

MATERIAL AND METHODS

Modified chamber KV 150-M2 was used for measurement of the monitored characteristics. The scheme of a chamber is shown in Figure 1. Dust clouds in this unit are carried out mechanically. From the tank with volume 6 litres of compressed air, the compressed air is transmitted through fast opening electromagnetic valve into the inner space of chamber with the volume of 291 litres. The sample is located on a plate and spread by compressed air with pressure 9.5 bar. The compressed air is directed to the sample through the metal profiled sheeting. After spreading, the sample is ignited by nitrocellulose igniter of one chamber. The igniter works on a resistive principle. Immediate ignition of nitrocellulose is achieved by the power source with parameters 48 V and 6.8 A, which is supplied to the resistance wire and results in an immediate burn and interruption of wire. The ignition energy of nitrocellulose used in the initiator was 10 kJ.

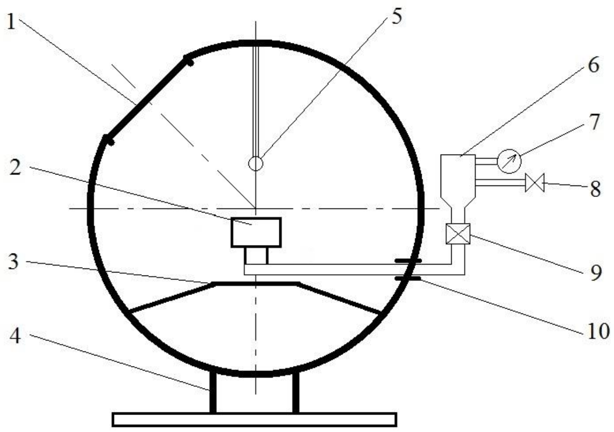

Fig. 1 *Scheme of a modified chamber of KV 150-M2 (1- lid, 2- disperser, 3- desk, 4- base, 5- nitrocellulose igniter, 6- vessel, 7- manometer, 8- compressed air inlet valve, 9- fast opening electromagnetic valve, 10- window*

Ignition of dust and dispersing of the dust is timed with dual digital timing relay. The relay has a fixed time interval between the opening of fast-opening valve and with connecting power to clamps of initiator. Time delay was set on 260 ms. The pressure changes inside the chamber were recorded through pressure transducer with mA output and the maximum measurable overpressure value of 16 bar. The pressure transducer was powered by a stabilized 24 V DC source. Response time of pressure transducer was 1 ms and the current value was recorded through the datalogger. Wood dust was used for the measured samples. Particle size of samples is shown in Table 1.

Table 1 Particle size of wood dust samples

Particle size	**Sample 1 $\%_{wg.}$**	**Sample 2 $\%_{wg.}$**
250 – 500 μm	55.81	0.41
200 - 250 μm	12.05	0.12
150 - 200 μm	6.78	1.63
90 - 150 μm	9.07	1.15
56 - 90 μm	7.41	47.45
0 - 56 μm	8.87	47.79
median value:	276 μm	58 μm

Measurement of parameters was carried out on the apparatus described above. The igniter was nitrocellulose with the weight ranging from 1.25 to 1.40 g. As mentioned above, the weight of the nitrocellulose is corresponding to the initiator energy value of 10 kJ.

The current in the circuit was measured by 269.3 Ω resistor with data logger. The values were recorded at the rate of 2000 values/second. The recording of the pressure changes during the explosion of dust clouds was measured with concentrations rang of 30 - 500 g/m^3.

RESULTS AND DISCUSSION

The values of pressure depending on the time which were obtained by the measurement are shown in Figures 2 - 6. The results suggest that when the concentration of the dust increases with the increase of the pressure value and the pressure rise value in the chamber.

Table 2 shows explosion characteristics of the wood dust clouds samples at various concentrations.

Table 2 The explosion characteristics of wood dust

Concentraction (g/m^3)	Sample 1		Sample 2	
	Pmax (bar)	dP/dt (bar.s^{-1})	Pmax (bar)	dP/dt (bar.s^{-1})
100	1.02	6.19	–	–
200	4.05	14.14	5.64	53.11
300	8.30	53.41	9.48	108.31
400	**8.49**	**52.77**	**9.74**	135.36
450	–	–	9.66	**164.04**
500	8.18	37.83	9.31	122.06

$$K_{st,s1} = dP/dt_{\max} \times \sqrt[3]{V} = 52.77 \times \sqrt[3]{0.291} = 35.0 \text{ bar.s}^{-1}\text{.m}$$

$$K_{st,s2} = dP/dt_{\max} \times \sqrt[3]{V} = 164.04 \times \sqrt[3]{0.291} = 108.7 \text{ bar.s}^{-1}\text{.m}$$

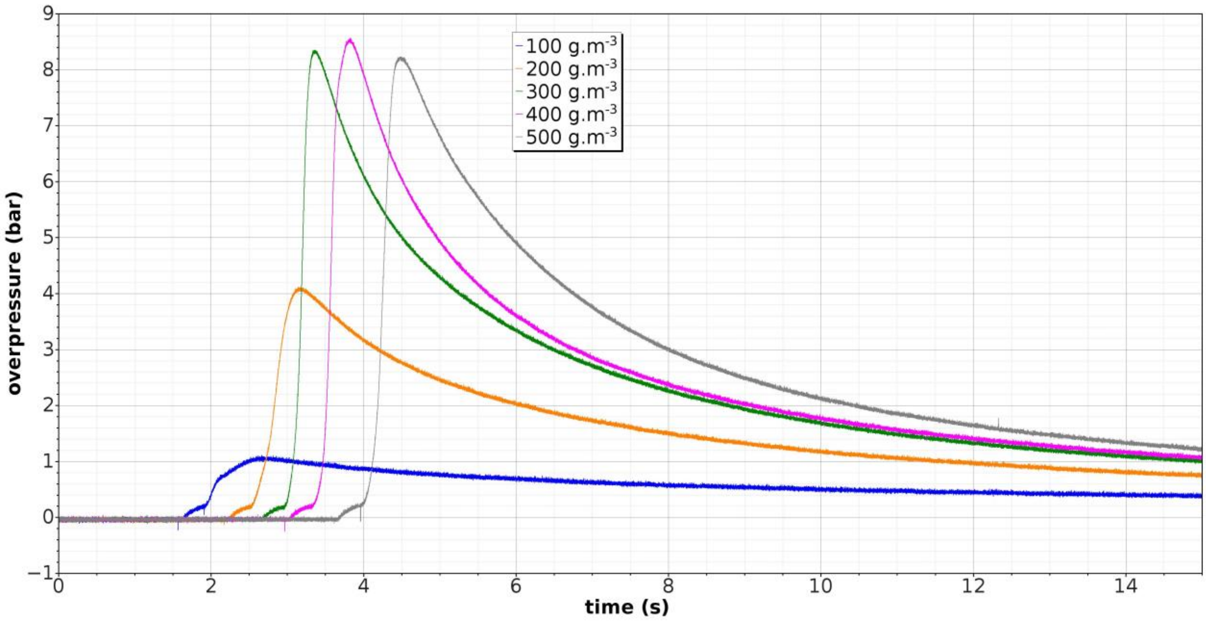

Fig. 2 *Explosion pressure of sample 1 at various concentrations*

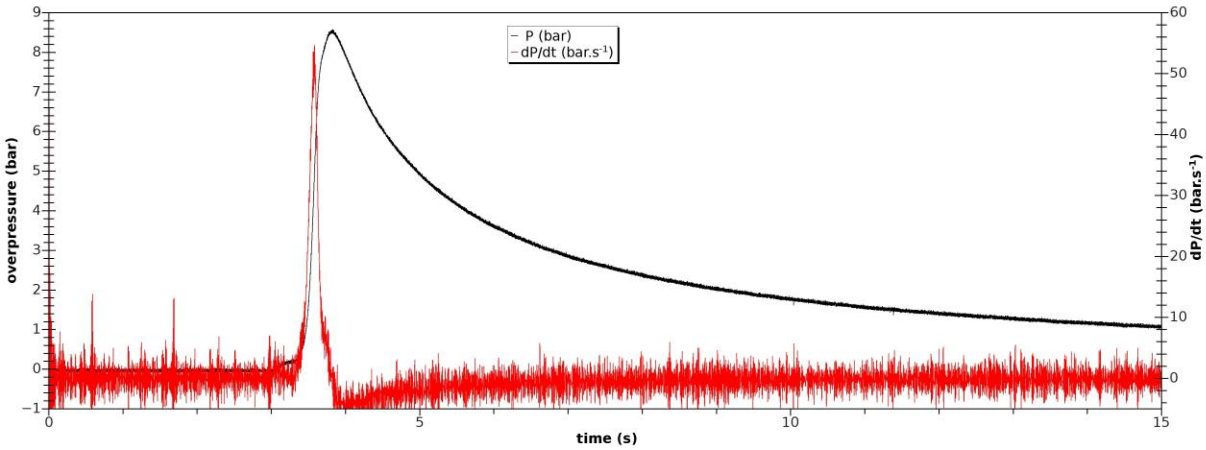

Fig. 3 *Explosion pressure P and pressure rise dP/dt of sample 1 with the concentration of 400 g/m^3*

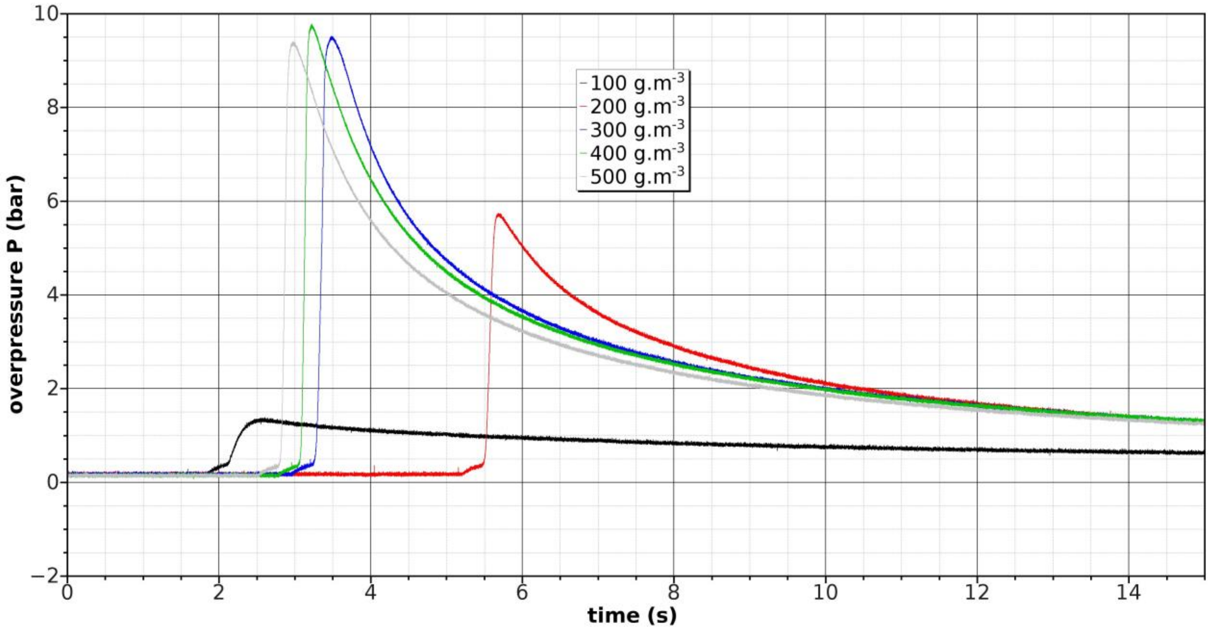

Fig. 4 *Explosion pressure of sample 2 at various concentrations*

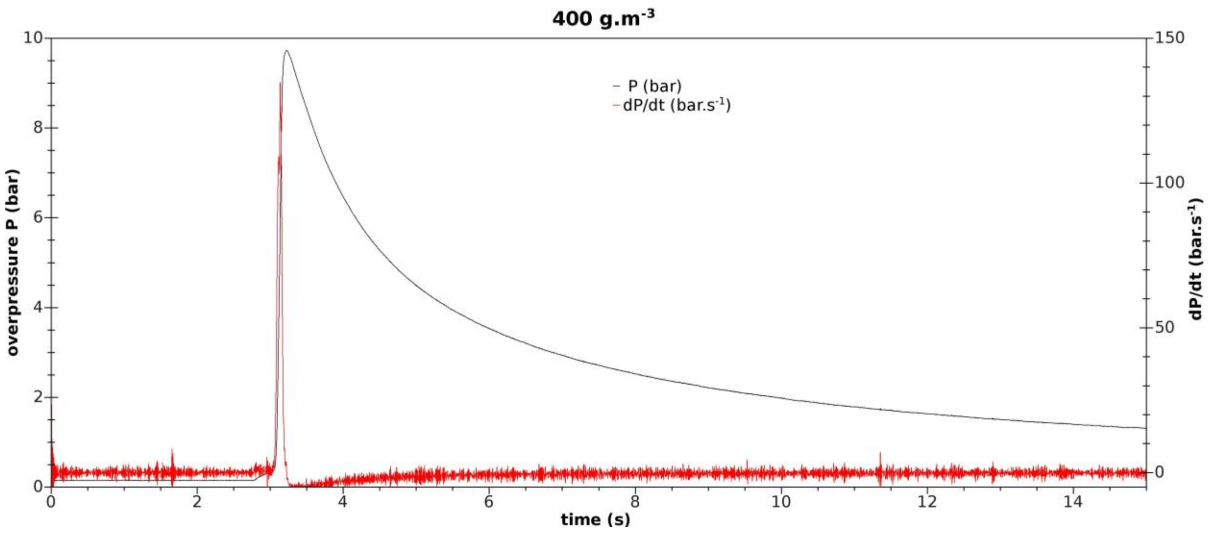

Fig. 5 *Explosion pressure P and pressure rise dP/dt of sample 2*
at the concentration of 400 g/m^3

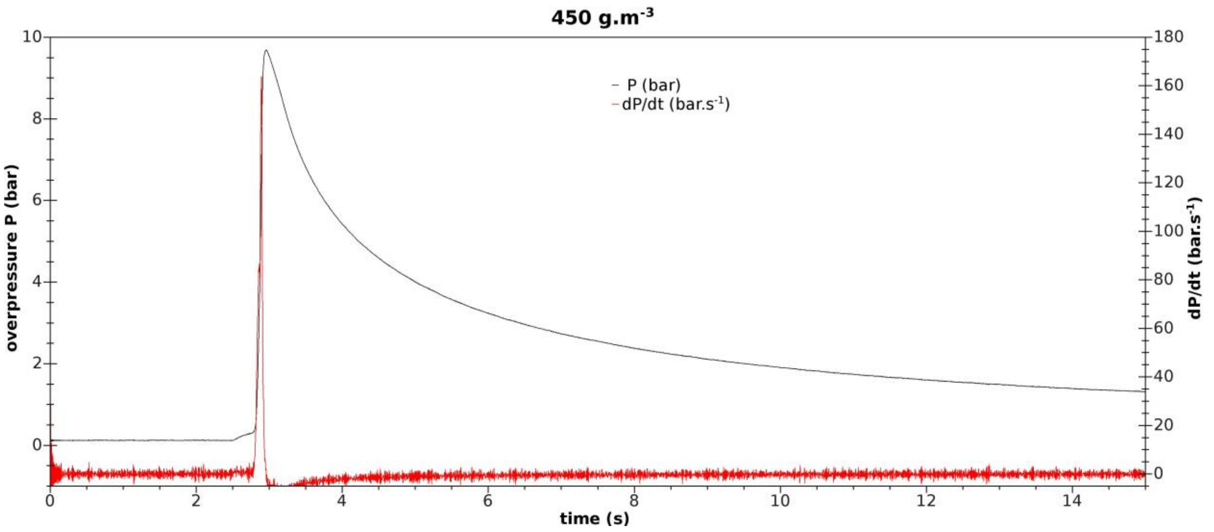

Fig. 6 *Explosion pressure P and pressure rise dP/dt of sample 2 at the concentration of 450 g/m³*

CONCLUSIONS

Testing the explosions of wood dust clouds by the device which parameters were described above was found that the maximum value of the pressure of sample 1 (median value of particle size 276 μm) was reached at the concentration of 400 g/m³ and its value is 8.49 bar.

The maximum value of the pressure of sample 2 (median value of particle size 58 μm) was reached at the concentration of 400 g/m³ and its value is 9.74 bar. Explosion constant K_{st} of sample 1 was calculated for the concentration of 400 g/m³ and its value is 35.0 bar.s^{-1}.m. Explosion constant K_{st} of sample 2 was calculated for the concentration of 450 g/m³ and its value is 108.7 bar.s^{-1}.m.

On the basis of the measurements, we found that the distribution of the particles has a significant impact on the parameters of wood dust samples. It can be concluded that the sample with smaller particles has higher explosion parameters.

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