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DETERMINATION OF THE EXPLOSION CHARACTERISTICS OF WHEAT FLOUR

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Abstract

The article deals with the measurement of explosion characteristics of wheat flour. 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, 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 and LEL according to STN EN 14034-3+A1:2011 Determination of explosion characteristics of dust clouds: Determination of the lower explosion limit LEL of dust clouds. The testing of explosions of wheat flour dust clouds showed that the maximum value of the pressure was reached at the concentrations of 600 g/m*^{3} *and its value is 8.32 bar/s. The fastest increase of pressure was observed at the concentration of 750 g/m*^{3} *and its value was 54.2 bar/s.*

Key words

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

INTRODUCTION

The majority of powders that are used in the processing industries are combustible (also referred to as flammables or explosibles). An explosion occurs if the concentration of the combustible dust suspended in the air is sufficient to propagate flame when ignited by a sufficiently energetic ignition source (1).

A dust explosion is initiated by the rapid combustion of flammable particulates suspended in the air. Any solid material that can burn in the air will do so with violence and at the speed that increases with the degree of sub-division of the material (2). The higher the degree of sub-division (in other words smaller the particle size), the more rapid and explosive the burning, until the limiting stage is reached when particles too fine in size tend to lump together. If the ignited dust cloud is unconfined, it will only cause a flash fire. But if the ignited dust cloud is confined, even partially, the heat of combustion may result in rapid development of pressure, with the flame propagation across the dust cloud and the evolution of large quantities of the heat and reaction products. The furious pace of these events results in an explosion. Besides the particle size, the violence of such an explosion depends on the rate of energy release, which is due to the combustion relative to the degree of confinement and heat losses. In exceptional situations, a destructive explosion can occur even in an unconfined dust cloud if the reactions caused by combustion are so fast that pressure builds up in the dust cloud faster than it can be dissipated at the edge of the cloud (3).

The explosion pentagon illustrated in Figure 1 expands the basic fire triangle to include the mixture of the fuel and oxidant and confinement of the mixture. The first of these additional components illustrates the above-mentioned key difference between the dust and gas explosions—a solid rather than a gaseous fuel. A gas explosion therefore involves a homogeneous system in which the smallest entities of fuel and air are separated only by molecular distances. Thorough mixing of fuel and oxidant is readily achieved and gravitational effects are negligible. However, in the dust/air mixture, the dust particles are strongly influenced by gravity; an essential prerequisite for a dust explosion is the formation of a dust/oxidant suspension. Once combustion of the resultant mixture occurs, confinement (either partial or complete) permits an overpressure to develop, thus enabling a fast-burning dust flame to transit to a dust explosion (4).

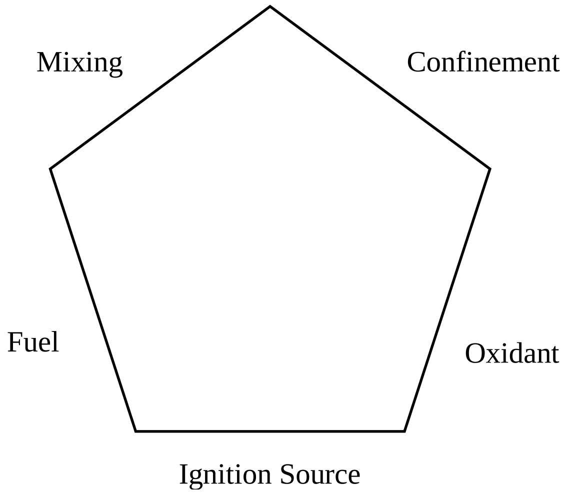

Fig. 1 *The explosion pentagon (5)*

Properties of dust clouds and settled dust are characterized by Lower Explosive Limit (LEL), the maximum explosion characteristics (maximum explosion pressure p_{max}, the maximum rate of explosion pressure rise $(dp/dt)_{max}$), the minimum *ignition* energy $E_{min,}$ *the* minimum ignition temperature of dust clouds t_{roz}, induction period for ignition τ_i and limiting oxygen concentration (LOC) (6).

The current article describes the measurement of the maximum explosion pressure and maximum rate of pressure rise of wheat flour 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 (7).

MATERIAL AND METHODS

Modified chamber KV 150-M2 was used to measure the monitored characteristics. The scheme of chamber is shown in Figure 2. Dust clouds in this unit are carried out mechanically. From the tank with the volume of 6 lifters, compressed air is transmitted by fast opening electromagnetic valve to 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. This compressed air is directed to the sample through the metal profiled sheeting. The sample is ignited by one chamber nitrocellulose igniter after the spreading of the sample. The igniter works on a resistive principle. Immediate ignition of nitrocellulose is achieved by the power source with the parameters of 48 V and 6.8 A, which is supplied to resistance wire and results in an immediate burn and interruption of wire. Ignition energy of nitrocellulose used in initiator is 10 kJ.

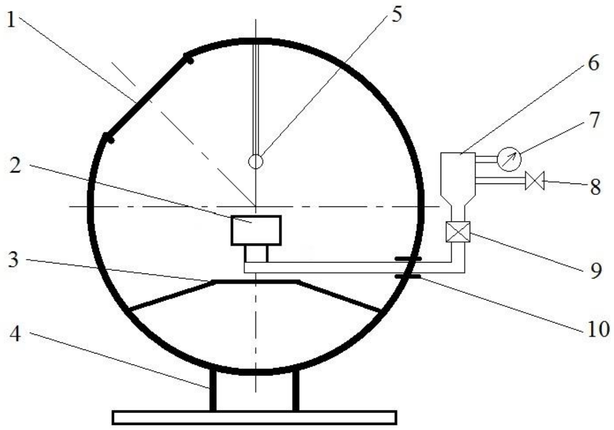

Fig. 2 *Scheme of modified chamber KV 150-M2 (1- lid, 2- nozzle for spreading the sample, 3- desk, 4- base, 5- nitrocellulose igniter, 6- vessel, 7- manometer, 8- compressed air inlet valve, 9- fast opening electromagnetic valve, 10- window*

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

Table 1 Particle size of wheat flour

Particle size	**%**
> 500 μm	0.00
250 – 500 μm	0.13
150 – 250 μm	5.76
90 – 150 μm	33.94
71 – 90 μm	24.18
56 – 71 μm	22.53
0 – 56 μm	9.05
median value:	84 μm

Moisture content of the wheat flour sample was 15 % wg. Measurement of parameters was carried out on the apparatus described above. The igniter was nitrocellulose with a weight from 1.15 to 1.35 g. As mentioned above, the weight of the nitrocellulose corresponded to the energy of the initiator with the 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 at these concentrations: 30 g/m^3, 60 g/m^3, 100 g/m^3, 125 g/m^3, 150 g/m^3, 200 g/m^3, 250 g/m^3, 300 g/m^3, 400 g/m^3, 500 g/m^3, 600 g/m^3, 675 g/m^3 and 700 g/m^3.

RESULTS AND DISCUSSION

The values of pressure depending on the time which were obtained by the measurement are shown in Figure 3.

The individual concentrations are colour coded in the graphs.

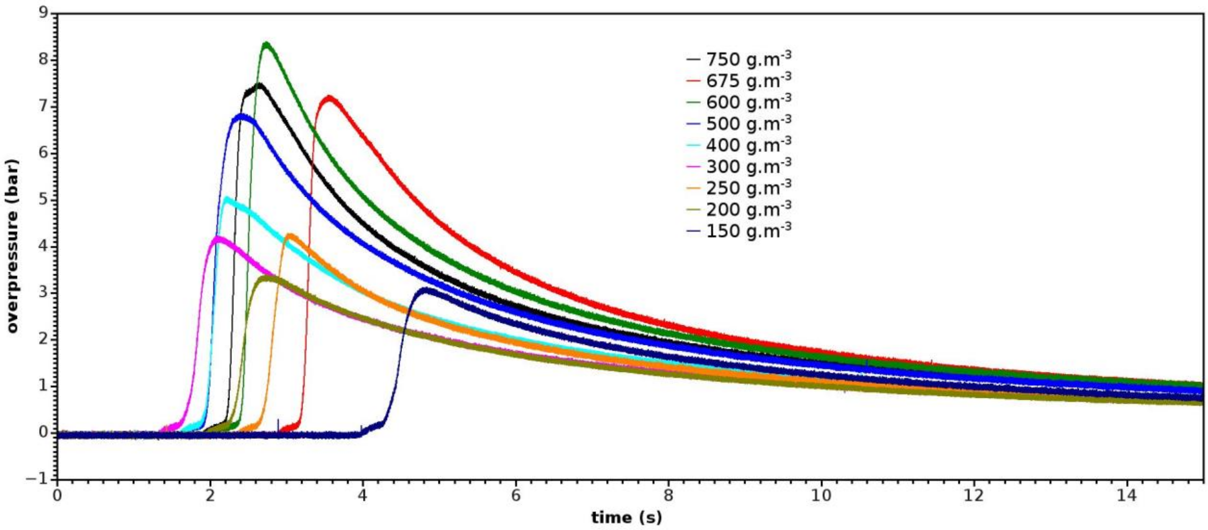

Fig. 3 *The maximum pressure obtained during the explosion of what flour clouds depending on the concentration of dust, concentrations: 150 - 700 g.m^{-3}*

From the results it can be concluded that when the concentration of the dust increases, the pressure value in the chamber also increases. The increase of pressure is very low at the concentration of 350 g/m^3, and therefore it can be concluded that for the terms of the experiment (300 ms timing) the pressure of 8 bar is maximum that can be achieved.

From the measured results of time-pressure values measured in an explosion of wheat dust clouds inside the chamber, the rate of pressure rise can be further assessed. This article presents the rate of pressure rise for the concentration of 300 g/m^3, 500 g/m^3, 600 g/m^3 and 750 g/m^3.

The value of explosion pressure rise per unit of time with increasing value of concentration increases, but this dependence is not linear. The highest value of explosion pressure rise is at the concentrations of 750 g/m^3 54.24 bar/s.

Table 2 shows the rate of exposure pressure rise of wheat dust clouds for individual concentrations.

Table 2 The explosion characteristics of wheat flour

Concentration (g/m^3)	P_{max} (bar)	dP/dt (bar)
150	3.04	11.79
200	3.30	16.98
250	4.23	18.42
300	4.16	19.28
400	4.99	27.99
500	6.78	38.82
600	**8,31**	51.71
675	7.17	50.56
750	7.40	**54.24**

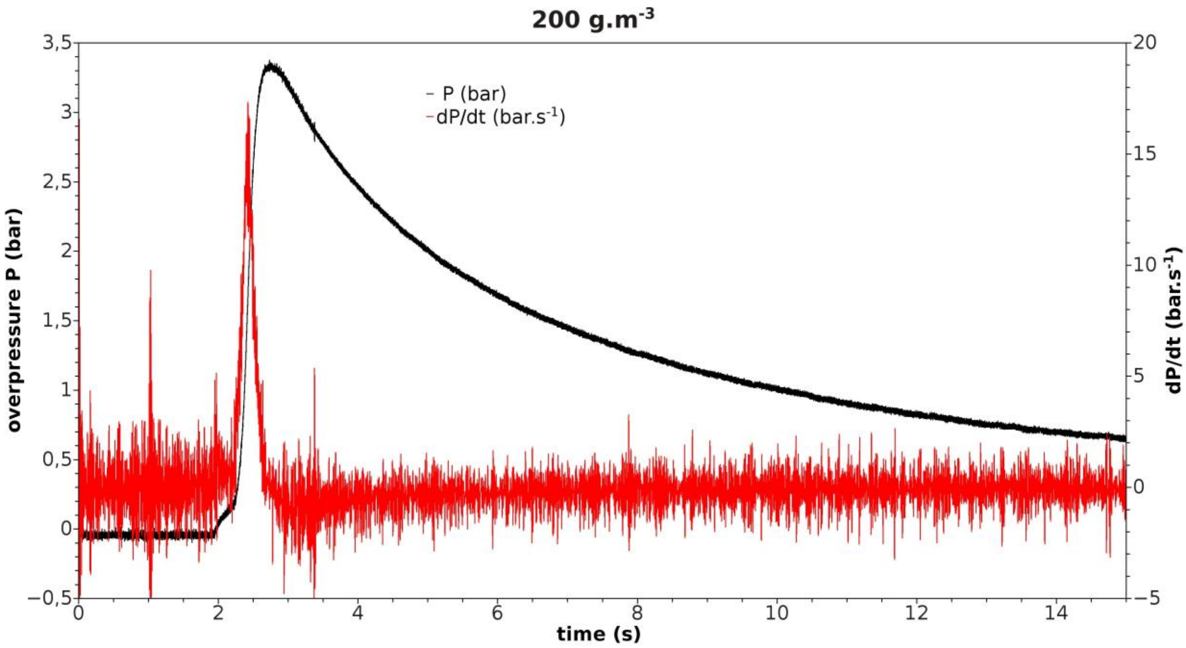

Fig. 4 *Explosion pressure of wheat flour dust clouds in the concentration of 200 g/m^3 and explosion pressure rise*

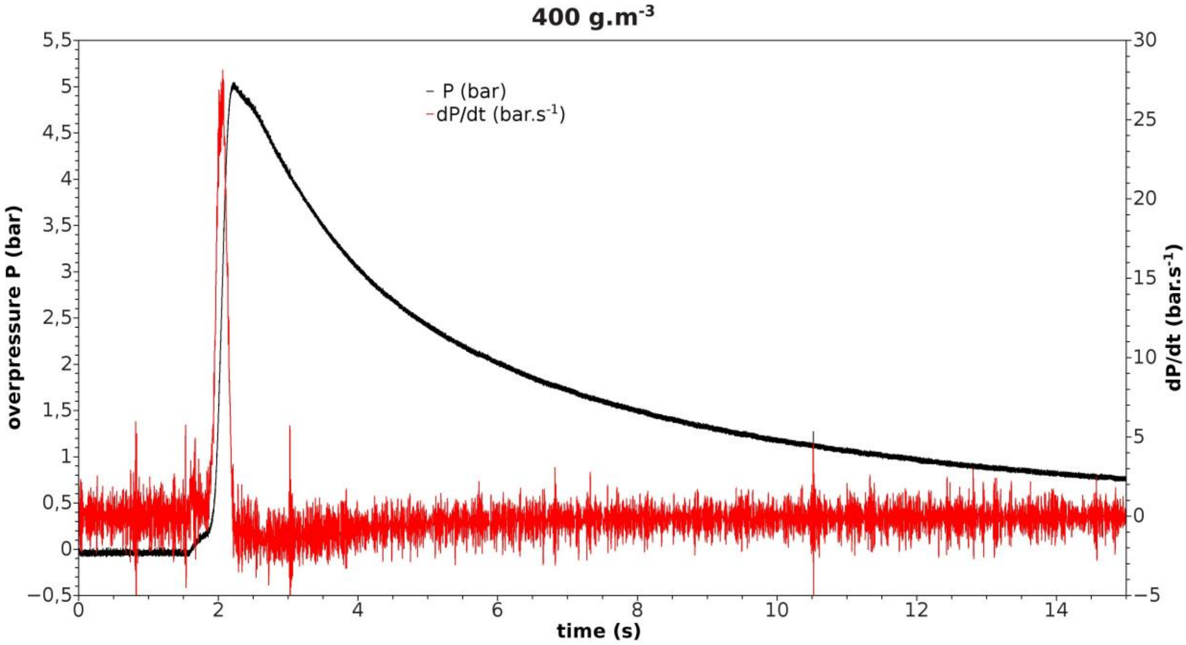

Fig. 5 *Explosion pressure of wheat flour dust clouds in the concentration of 400 g/m*^{3} *and explosion pressure rise*

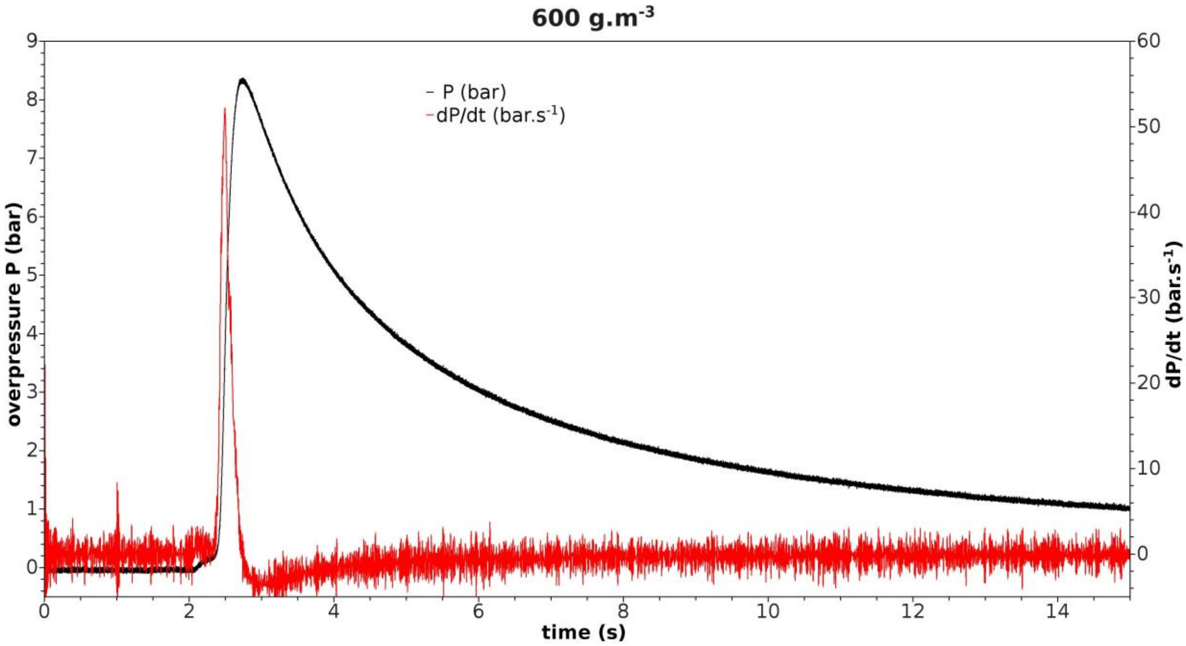

Fig. 6 *Explosion pressure of wheat flour dust clouds in the concentration of 600 g/m*^{3} *and explosion pressure rise*

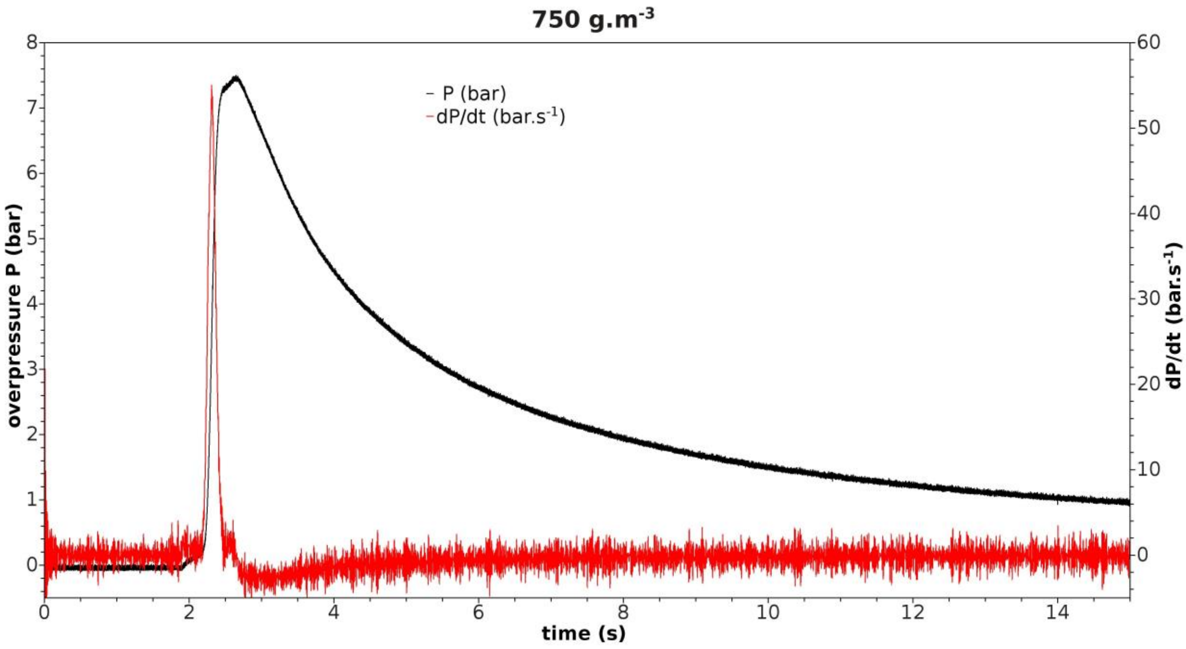

Fig. 7 *Explosion pressure of wheat flour dust clouds in the concentration of 750 g/m³ and explosion pressure rise*

CONCLUSIONS

The testing of explosion characteristics of wheat flour dust clouds proved that the maximum value of the pressure was reached at the concentrations of 600 g/m^3 and its value is 8.31 bar. The fastest increase of pressure was observed at the concentrations of 700 g/m^3 and its value was 54.24 bar/s. Lower explosion limit of wheat flour was 60 g/m^3.

Managing explosion hazards involves first characterization of the explosion properties of materials through testing. Once characterized, the hazard can be managed through clear determination of the prevention and protection objectives, followed by selection and implementation of the appropriate protection methods (8).

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