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EXPLOSIVE PROPERTIES OF COMBUSTIBLE WOOD DUST

Abstract: In many industries, there are combustible industrial dust in some parts of production or processing technologies, which, when specific conditions are met simultaneously, can result in massive explosions. In order to achieve anti-explosion prevention in industrial operations, it is necessary to know the explosion properties and fire parameters of the industrial dust that occurs in the given industrial plant. The article deals with the explosive properties of wood combustible dust and with the possible solutions for explosion protection in wood processing plants.

Key words: explosion, industrial dust, explosion protection, industrial safety

INTRODUCTION

Explosions of dust mixtures are frequently underestimated in practice, despite the fact that a very small amount of stirred-up dust can cause a powerful explosion when ignited, resulting in not only property damage but also damage to human health or even death. Industrial dust explosion represents a great danger for building structures and production technologies which may contain other dangerous substances that, if released, could cause additional harm.

As a result of the constant development of production technology, new materials are created, necessitating the determination of their explosion and fire properties for safe use during production, storage and transportation. The area of explosion testing of materials and their parameters is carried out in testing facilities by experimental measurements. The goal of the work is the application of the acquired knowledge in the field of explosion protection of combustible industrial dust.

One of the most frequently occurring combustible industrial dust is the dust from the processing of almost all types of wood. The validity of such tests is also proven by the statistics, which clearly show a large number of fires and dust explosions in the area of the woodworking industry.

The minimum explosion temperature of Pinus Sylvestris (pine tree) and Larix Decidua (red spruce) were measured in The Fire – Chemical Laboratory of the Faculty of Security Engineering, University of Žilina, Slovakia. The minimum ignition temperature was observed depending on the particle size of wood dust obtained directly from a specific woodworking technology for the production of furniture and other wooden goods.

Table 1. *Fires in selected industries in 2016 – 2021 in Slovakia [1]*

Industry	Number of fires
Food and beverage producing and tobacco processing	104
Textile production	13
Publishing and printing	7
Leather processing and production of leather goods	13
Wood processing and production of wood goods	**261**
Cellulose processing and paper goods production	41
Other industrial production	70

Table 2. *Fire rate by cause in Žilina region in years 2016 - 2021, Slovakia [1]*

Year	Number of explosions	Number of injured persons	Number of people died
2016	31	22	3
2017	28	43	6
2018	37	30	2
2019	37	27	1
2020	26	23	1
2021	20	17	1
Total	**179**	**162**	**14**

PRINCIPLES OF THE DUST EXPLOSION

Physical and chemical properties of combustible industrial dust

The basic physical properties of dust include particle size and shape, settling time, humidity, electric charge, stickiness, wettability, bulk density, explosiveness, etc. The distribution of dust depending on the particle size is defined in Table 3. Due to the size of the particle, dust is divided into macro-, micro-, ultra-, and submicroscopic. [2]

Table 3. *Dividing of combustible dust according to particle size [2]*

Dust	Particle size
Macroscopic	bigger than 0,01 mm
Microscopic	0,01 mm - 0,00025 mm
Ultramicroscopic	0,00025 mm - 0,0001 mm
Submicroscopic	smaller than 0,0001 mm

Fire and explosion parameters of combustible industrial dust

In the case of flammable gases and liquids, most parameters can be found in safety data sheets or from other suitable sources. In the area of combustible dust, the situation is more complicated. In the professional literature, values are also given for flammable and explosive dust, but as intervals of a larger range, having a rather informative nature. In the case of combustible dust, the parameters always depend on the specific technology and their handling.

Because determination by calculation is not yet possible, the most reliable way to obtain the most accurate information about a substance's explosiveness or flammability is to take a specific sample and experimentally measure its properties in the laboratory.

Explosion conditions

In order for an explosion to occur, the explosive substance must have a concentration in the range of its explosiveness, which approximates Figure 1. If the substance is below the LEL – lower explosion limit (c_{min}), there is a large proportion of the oxidizing agent and a small proportion of the substance in the mixture. Such a mixture is not explosive. If the substance is above the UEL – upper explosion limit (c_{max}), the mixture contains too much explosive substance and lacks an oxidizing agent. The mixture is also not capable of explosion, but it can burn if there is sufficient air access. The substance burns explosively in the interface between LEL and UEL within the limits of the so-called explosive range. The y-axis shows the increase in pressure resulting from the explosion $P_{expl.}$ and the x-axis the concentration of the flammable substance c. [3]

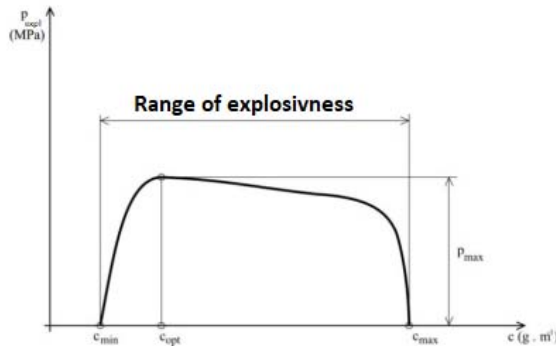

Figure 1. Explosion limits [4]

Explosion protection

The basic measure to prevent an explosion with active explosion protection is [2]:

• substitution of flammable substances for inert substances,

• limit the concentration of flammable substances to a safe level,

• eliminate the occurrence of initiation sources,

• minimize the amount of settled combustible dust by regularly removing it without stirring it into the space.

In case of impossibility or insufficient application of active protection, means of passive protection are applied in the form of protective structures in the following manner [5]:

• To be resistant to explosions.

• To relieve the explosion - it is not about preventing the explosion process, but about releasing the explosion outside the safe area (reducing the explosion pressure), most often outdoors.

• To suppress an explosion - the device, most often in the form of a container, contains a suitable extinguishing agent to prevent the initiation of an explosion. The most applied type is the HRD (high rate discharge) system.

• To prevent the transfer of flame and explosion - the transfer of flame or explosion through conveying systems, pipelines, and other elements of production systems can be prevented by using rotary feeders, quick-closing valves, dampers, relief stacks, explosion-proof barriers or gate valves.

RESEARCH METHODS

Determination of the minimum ignition temperature of selected wood dust depending on particle size was carried out in the premises of the fire-chemical laboratory of the Faculty of Security Engineering at the University of Žilina. The Slovak technical standard method was used for measurement STN EN 50281-2-1 – Electrical equipment for areas with combustible dust. Part 2-1: Test methods. Methods for determining the minimum ignition temperatures of dust. This norm states two test methods for determining the minimum dust ignition temperatures [6]:

- Method A: A layer of dust on a heated surface of constant temperature.
- Method B: Stirred powder in a constant temperature furnace.

In order to meet the objectives of the work, method B was used in the measurement.

A ceramic heating tube - furnace (2) is attached vertically to the iron frame (1). With the help of the compressor hose (3), the air is pressurized, which is admitted to the compressed air reservoir (5) through the valve (4). The pressure gauge (6) shows the air pressure in the compressed air tank. The powder is placed in the dust container (7), which, after releasing the compressed air valve (8), is sprayed into a ceramic furnace with a constant temperature, which is regulated by the connected temperature controller (9). We observe a possible ignition on the mirror (10).

Figure 2. *The testing device*

The samples were sieved through sieves with a metal insert for selection based on particle size, and then the measurement itself was carried out. The air was pressurized to 0.2 bar by a valve in the container with compressed air, and a sample weighing 0.1 g was placed in the clean dust container. During the measurement, the temperature of the furnace was regulated and the type of sample was varied. The work is dominated by the determination of the dependence of the minimum ignition temperature of stirred wood dust on the particle sizes, therefore both the constant pressure and the constant mass of the dust were used in the measurement.

After the adequate pressure was set, the sample was placed and the required temperature was reached, the compressed air valve was released with a button and the dust load was sprayed into the furnace tube.

The course of possible ignition was monitored in the space under the tube. The minimum ignition temperature was considered to be the temperature at which wood dust ignited in three successive attempts.

RESEARCH HYPOTHESIS

It is assumed that the minimum ignition temperature is reached at a lower value in the group of measured and analysed wood dust samples the finer the combustible industrial dust and, consequently, the smaller its particle size.

RESEARCH RESULTS

The measurement results prove the dependence of the particle size of wood dust and the minimum ignition temperature. As the particle size of wood dust decreases, the temperature required for its ignition also decreases. In the case of measuring the minimum ignition temperature of the stirred wood dust of forest pine tree, the temperature was set at 343 °C for the particle size of 0.50 mm, for the dust with the particle size of 0.315 mm at 343 °C, for the dust fraction of 0.20 mm at 338 °C C and 0.16 mm at 333 °C. In the case of measuring red spruce, an even smaller temperature difference was observed - 418 °C (0.50 mm), 416 °C (0.315 mm), 415 °C (0.20 mm) and 414 °C (0.16 mm). Even if the differences in the minimum ignition temperatures of individual fractions of wood dust are minor, it is reasonable to conclude that the finer the dust, the more dangerous it is in the event of an explosion, and the more important it is in terms of explosion prevention. The experiment proves the fact that dust in production operations is explosive.

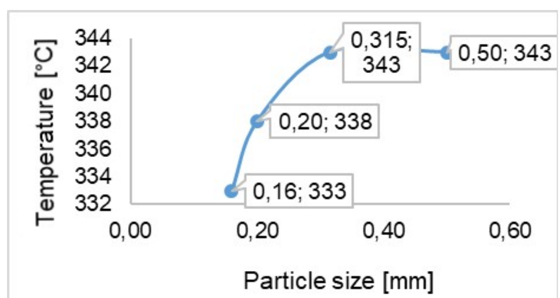

Figure 3. *Dependence of minimum ignition temperature on particle size of forest pine wood dust in a stirred state*

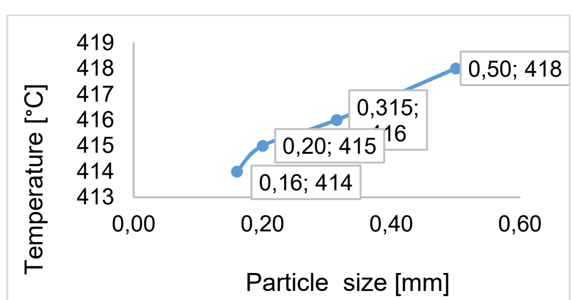

Figure 4. *Dependence of minimum ignition temperature on particle size of red spruce wood dust in a stirred state*

CONCLUSION

Homogeneous samples of Pinus Sylvestris (pine tree) and Larix Decidua (red spruce) were used for the experiment. However, if the dust collected in the bags of extraction devices in the woodworking plant is not homogeneous (it changes with the orders of customers), it is important to start with explosion protection by knowing the partial minimum ignition temperatures of selected types of combustible wood dust. Subsequently, a SWOT analysis was applied to the operation in order to reveal strengths and weaknesses (in the internal environment of the operation) and opportunities and threats (from the external environment), which result from the level of security of the operation against explosions.

In addition to active explosion protection (continuous removal of wood dust by suction, removal of potential initiation sources, etc.), opportunities for the company include the possibility of completing construction systems for protection against fires and explosions (secondary explosion protection), optimization of production processes (renewal and introduction of new technological innovations, e.g. in areas of extraction of wood waste, machines with a more efficient grinding method, etc.)

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BIOGRAPHY of the first author

Miroslava Vandlíčková was born in Čadca, Slovak Republic, in 1978.
She received the diploma in chemical engineering at The Slovak Technical University in Bratislava, Slovak Republic and the Ph.D. degree in physical chemistry at The Palacký University in Olomouc, Faculty of Natural Sciences, Czech Republic.
Her main areas of research include explosion protection of industrial plants with the occurrence of combustible industrial dusts, dangerous substances and CBRNE substances.
She is currently working as a lecturer of physical chemistry, explosion protection, and CBRN substances and as a vice-dean for education at the Faculty of Security Engineering, University of Žilina, Slovak Republic.

EKSPLOZIVNA SVOJSTVA ZAPALJIVE DRVNE PRAŠINE

Miroslava Vandlíčková, Soňa Stenchláková

Rezime: *U mnogim industrijama prisutna je zapaljiva industrijska prašina u pojedinim delovima proizvodnih ili prerađivačkih tehnologija, koja može izazvati velike eksplozije kada se paralelno postignu određeni uslovi. Da bi se postigla protiveksplozijska prevencija u industrijskim operacijama, neophodno je poznavati eksplozivna svojstva i požarne parametre industrijske prašine koja se javlja u datom industrijskom postrojenju. Članak se bavi eksplozivnim svojstvima drvne zapaljive prašine i mogućim rešenjima zaštite od eksplozije u postrojenjima za preradu drveta.*

Ključne reči: eksplozija, industrijska prašina, zaštita od eksplozije, industrijska bezbedno