Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 86, 2014:138-143
(Ann. WULS - SGGW, For. and Wood Technol. 86, 2014)

Effects of particle size on minimum ignition temperature of dust layers and dust clouds of selected wood dusts

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Abstract*:* This paper presents the results of the minimum ignition temperature of dust layer and cloud of dusts. Tests have been performed for selected dusts obtained from European and exotic wood species. Tests have been performed in accordance with EN 50281-2-1. Method A consists in determining the minimum temperature at which ignition occurs of dust and/or its decomposition on hot plate at a constant temperature. The study is used to identify the threats from industrial equipment and construction, which while working have hot surfaces, on which can create a layer of combustible dust. Method B is used for determining the minimum ignition temperature of dust cloud or other particulate solids. Method B is complementary to the method A. It is used in relation to industrial equipment, inside which dust may exist in the form of short-term cloud. The results obtained for finer dusts, i.e. 200 and 71 μm were nearly equal. The differences reaching from 10 to 30°C were observed for dust samples of mean diameter finer than 71 μm. Based on conducted research, it is possible than to order particular types of dusts according to diminishing minimum temperature of dust cloud/layer ignition as follows: oak dust ≥ eucalyptus dust > lapacho dust.

Keywords: wood dust, dust cloud, dust layer ignition, hazard of dust

INTRODUCTION

In industries that manufacture, process, generate, or use combustible dusts, an accurate knowledge of their explosion hazards is essential. Dust explosions have been a recognized threat to humans and property for a long time (Eckhoff 2011). At industry conditions the presence of dust determine the fire and explosion hazard, among others. It concerns different industries. In Poland, the biggest fire and explosion hazard posed by dust is attributable to extractive and wood industries. Considerations on the type problems and scale of the threat depend on the area and way of appearing. Recently in Poland the only wood used for the industry was the one of Polish and European origin. However, in last few years a rising interest in exotic wood was observed (Wesselink and Ravenshort 2008, Scott et al. 2011, Jaskółowski et al. 2010, Jaskółowski et al. 2011), as aesthetic values make them competitive to the ones of European origin. Wood made of exotic species, present on polish market since several years, gradually earns the trust of rising group of supporters. Growing demand for floors, veneers and slabs made of exotic wood is observed. Despite considerable differences in their external appearance, different physical properties of exotic wood should be emphasized. During wood production, scrap material like dust should be expected. It poses considerable danger for employees' life and health (occupational safety and health) and fire and/or explosion danger. The mechanism of combustion will be conditioned by either static condition - settled dust, or dynamic - aerosol dust. Accidental dust explosions are a major concern in many industries handling combustible dusts. Calculating the probability of the failure event associated with dangers in particular industry (e.g. fire, explosion) and its potential impact is an essential element of the risk assessment process. A fair dust explosion risk assessment is a thorough process involving the identification of all hazards, their probability of occurrence and the severity of potential consequences (Scott et al. 2011). The next step should be the determination of possible solutions that are expected to reduce calculated risk, after implementation.

Physical properties of the dust which is present in particular work environment determines the character of the danger. The analysis of available literature (El-Sayed and Abdel-Latif 2000, Lebecki et al. 2003, Dyduch et al. 2006) shows that most of it concerns mainly the danger made the airborne dust (aerosol). Moreover it concerns only the wood dust of European origin. However, dust deposition is as dangerous as the airborne dust. The presence of solid particles is mainly connected with the danger for smoldering but this process may cause an explosion, when started in the dust layer.

To ensure acceptable level of risk in the industry, explosion characteristics of particular dust should be determined. Among other parameters, these consists of e.g. ignition temperature of a 5 mm layer of dust (T_{5mm}) and ignition temperature of the dust cloud (T_{CL}). According to ATEX directive, hot surfaces of electrical devices should not exceed the value of 2/3 of minimal ignition temperature of dust cloud, and its temperature should be at least 75K lower than the ignition temperature of a 5 mm layer of dust (if dust deposits does not exceed 5 mm in height).

According to experimental tests, the dependence between flammability and values of ignition temperatures of hot surfaces can be determined and one can prevent and/or minimize the risk of fire and/or explosion of dusts.

As regards combustion process of solid materials, it was proved before, that the finer the mean particle diameter of a dust is, the more serious the consequences of possible explosion might be, as the combustion process and, consequently, explosion overpressure build-up will occur relatively faster. Taking into consideration hemicellulose, cellulose and lignin – three characteristic chemical compounds that the wood is composed of – during the first phase of pyrolysis, volatile matter (usually combustible gasses like: hydrogen, carbon monoxide, methane, and heavier hydrocarbons) is being released (Haiping et al. 2007). This phenomenon should be understood as the beginning of the combustion process. Therefore, the greater the surface-to-volume ratio of the particle will be, the heat exchange with the environment of a dust particle will be more intense, what will lead to faster pyrolysis.

MATERIALS AND METHODS

Wood samples (oak, lapacho, and eucalyptus) were planed into a dust, crumbled inside a vibratory disk mill. Vibrating screen was later used to separate different sized particles.

Eventually, three groups of dust samples of different mean diameters were obtained:

a) Finer than 71μm,
b) Between 71μm and 200μm,
c) Between 200μm and 500μm.

The research have been carried out into particular groups of dust samples.

Ignition temperature of dust was determined with the use of the methodologies described in PN EN 50281-2-1:2002. The determination of ignition temperature of layer was carried out using a test set as shown in fig 1. 5 mm high metal ring was placed on a furnace's hotplate, filled with dust and heated.

According to the test method, ignition of dust layer occurs if:

a) smoldering fire or flames are observed, or

b) dust temperature reached 450°C and transforms to smoldering fire or flames are observed, or

c) dust temperature is 250K higher than the temperature of the hotplate and transforms to smoldering fire or flames are observed.


Fig. 1. Apparatus for the determination of ignition temperature of dust layer

The determination of ignition temperature of dust cloud was carried out using the test stand shown in fig. 2. When the temperature of the furnace reaches required value, compressed air is used to form a dust cloud inside the vessel. The temperature is being decreased until the explosion does not occur. The minimum ignition temperature (MIT) is the lowest furnace temperature at which dust ignition is obtained (fig. 2), decreased by 20 K.


Fig. 2. Apparatus for the determination of ignition temperature of dust cloud

RESULTS AND DISCUSSION

The results of conducted research were shown in figs. 3 and 4. In the figs. 5 and 6, respectively, the ignition of a dust layer and dust cloud, that was observed during the experimental part of the research, was presented.

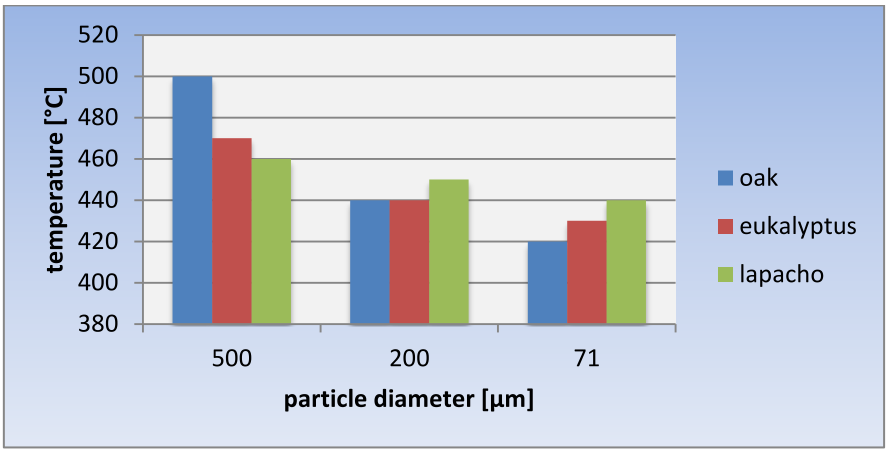

Figure. 3. Minimal ignition temperature of a dust cloud

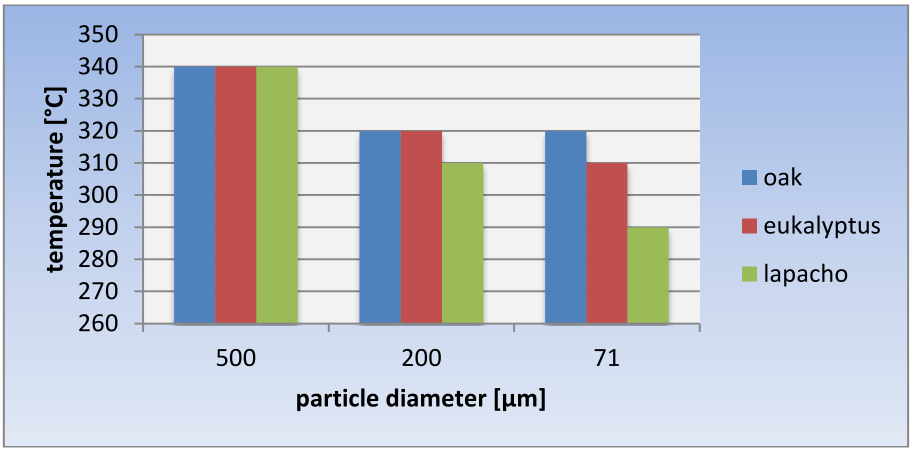

Figure. 4. Minimal ignition temperature of 5mm dust layer

Figure. 5. Ignition of a dust layer during experimental part

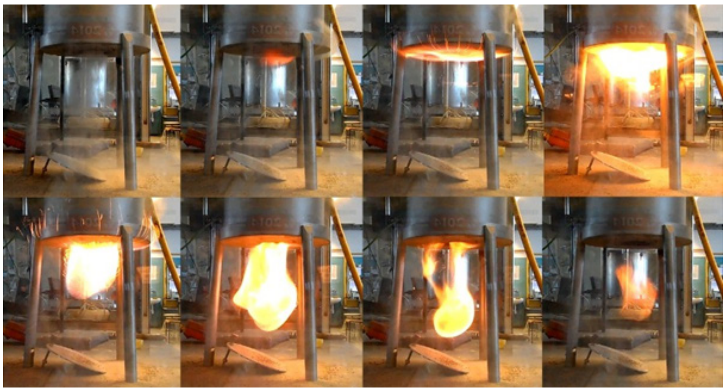

Figure. 6. Ignition of a dust cloud during experimental part

Presented research work was conducted in room temperature, i.e. 20°C and pressure equal to 1000 hPa. Results reveal the values of minimum temperature of dust cloud and dust layer ignition of different combustible dusts, posing slightly diversified fire and explosion hazard.

Based on the results of the conducted research, it might be stated that the most serious danger regarding the ignition of a dust layer, taking into consideration mean particle diameters of dust samples, was posed by the dust originating from lapacho wood.

All dust samples of mean particle diameter finer than 500 µm were ignited in the temperature of hot surface reaching 340°C. It might be concluded that dust samples characterized by coarser mean particle diameters pose relatively lower danger of dust cloud/dust layer ignition. Therefore, higher surface temperature will be necessary to initiate the ignition.

The results obtained for finer dusts, i.e. 200 and 71 μm were nearly equal. The differences reaching from 10 to 30°C were observed for dust samples of mean diameter finer than 71 μm. Based on conducted research, it is possible than to order particular types of dusts according to diminishing minimum temperature of dust cloud/layer ignition as follows: oak dust ≥ eucalyptus dust > lapacho dust.

CONCLUSIONS

In all industries, where dusts are present, either as a scrap material or raw material, fire and explosion hazard should be considered. Generally the statement might be made, that depending on the form in which the dust is present in particular industry, different hazard should be expected. If dust clouds are formed, the greatest hazard is connected with its explosion. On the other hand dust deposition poses fire hazard. However, these two phenomena are inseparable, as every dust layer may form a dust cloud and every dust cloud eventually deposits on a surface. Ones should also remember that fire may cause an explosion, as well as the explosion may subsequently cause a fire.

Despite the fact that small quantity of dust was used during the experiments, considerable flame was observed, as a result of ignition, as shown in the fig. 3. If related to macro – scale, it is easy to imagine the extent of the danger posed by dust explosions in the industry.

To prevent the ignition of dust in wood industry, ones should obey the law concerning fire and explosion safety, control potential ignition sources, and also ensure, if all occupational safety and health regulation are followed. It is vital to control maximal temperature of electric devices in the industry. The temperature of hot surfaces should not exceed 2/3 of minimal ignition temperature of dust cloud and should be at least 75K lower than minimal ignition temperature of 5mm dust layer.

It should be emphasized, that proposed logical order of dust samples is a relative concept. Fire and explosion danger posed by the dusts present in the industry should never be neglected. In other words, considering lapacho dust as more hazardous than oak dust, decision-makers should ensure the same safety level in the atmospheres, where potentially explosive atmosphere of airborne dust will be present.

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Streszczenie: *Badanie wpływu rozdrobnienia na temperaturę zapłonu warstwy i obłoku wybranych pyłów.* W artykule zaprezentowano wyniki badań wpływu stopnia rozdrobnienia na temperatury zapłonu warstwy i obłoku pyłów drzewnych otrzymanych : drewna dębowego, lapacho oraz eukaliptusa. Do badań wykorzystano metodykę pomiarową opisaną w normie PN-EN 50281-2-1:2002. Próbki miały średnicę: poniżej 71µm, pomiędzy 71µm a 200µm i pomiędzy 200µm i 500µm Wyniki badań umożliwiły uszeregowanie pyłów od stwarzającego największe do najmniejszego zagrożenia w następujący sposób: pył z drewna lapacho > pył z drewna eukaliptusowego ≥ pył z drewna dębowego. Ponadto badania potwierdziły, że mm mniejsza średnica ziaren pyłu tym szybciej dochodzi do zapłonu jego warstwy i obłoku. Biorąc pod uwagę stopień rozdrobnienia zauważyć można, że im pył bardziej rozdrobniony tym niższa jest jego temperatura zapłonu warstwy.

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