Risk of Biomass Dust Layer in Industrial Processes

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Abstract

The focus of this paper is on risks connected to dust layers of biomass orign in industrial processes. The production process leads to the formation of dust and dust layers. The transportation, storage and preparation for use are another very important source of biomass dust. The presence of dust layers is connected to risk of fire and risk of explosion. The paper deals with testing characteristics and testing methods of flame spread over dust layers.

Keywords: Industry, dust layer, explosive, test method.

Introduction

Biomass is more and more used in heat power plants as an alternative fuel besides the coal or as a supplement. There are certain risks resulting from the biomass and coal mixture properties. This paper deals with fire/technic characteristics and mainly with the dust layers presence. From fire characteristic point of view the ignition temperature, autoignition temperature, the temperature of incandescence, etc., but also parameters related to the explosion - the lower explosive limit and maximum explosion pressure need to be monitored. Because the fire may go in and multi explosion during the combustion can occur. Multiple explosion risk should not be forgotten. The dust is created especially during the transport and during the biomass modification when the dust escapes out. The dust sediments on flooring, constructions and equipment. It is very risky when its wirled and heated by some source of heat at the same time.

Renewable energy sources are more and more preferred to fossil fuels that become depletable. This trend is global. Biomass is used in various applications and its use is connected to the dust presence within the processes of biomass production, transport, storage and preparation. Biomass benefits and properties are well described by Müllerová[1-3], Víglaský[4,5], Motlík[5].

Biomass dust explosion risk

Flammable dust is defined by the European standard EN 60079-10-2 as following: 'It is a small solid with a nominal dimension of 500 μm or less, which can stir the air, can accumulate its own weight, can burn or glow in the air and may form explosive mixtures with air at atmospheric pressure and normal temperatures[6].

Biomass dust is an important parameter for the risk assessment of technologies in terms of potential risk and spread of fire[7]. The risk of fire due to high flammability was described by Eckhoff,[8] Palmer[9] and Damec[10]

Primary explosion: The **explosion** happens when five basic elements are present at the same time: combustible dust, oxygen in air, ignition, dispersion of dust particulates and confinement of dust clouds. Consequences are serious, when that five elements meet as flowing: Pellet dust caused an explosion and four-alarm fire at a wood pellet company. The explosion and fire happened August 20[th.] at Inferno Wood Pellets Co. Rhode Island, US. One worker was injured. He was thrown 20 feet because of the explosion and suffered first- and second-degree burns.[11] Stronger explosion happened in DeBruce Grain company, Haysville, US when the Grain Elevator exploded in 1998. Explosion killed 7 and injured 10 employees (figure-1)[12].

Figure-0
After explosion in DeBruce Grain Company[13]

Secondary explosion: Explosion is the main dust layer risk. Secondary explosion may occour after primary explosion formed the dust cloud and heat stress is present on the surface of device at the same time. The cloud of dust formed by primary explosion is also very explosive. In case of ignition by heat stress on the surface of device or by other ignitor the cloud explodes. This cycle can be repeated and lead to chain reaction of multiply explosions[13,14].

The following part describes the basic assumptions of combustion and also further parameters that influence the rate of spread of flame.

Flame Spread over the Dust Layer

Generally, fire is initiated when three basic conditions meet: Presence of flammable substances, Presence of an oxidising agent (e.g. atmospheric oxygen) in sufficient quantity and presence of an effective ignition source.

Combustion can be defined as physical-chemical process with external effect as heat and light[15]. Atmospheric oxygen is the most common oxidant applied. In solid form, the individual atoms or molecules are arranged in regular structures with high internal orderliness. With increased temperature flammable bonds break down and the substance is transformed from solid to liquid phase.

Considering ther temperature conditions when the machines in facilities are heated, the biomass get dehydrated by temperature above 100°C. The disintegration begins at a temperature of 130-150°C. These termperatures are reached when some problems occure and bearings, rolls and another segments get warmer. The monitoring of the temperature is necessary because by 180-195°C begins the disintegration and large amounts of gas is released. Then Exothermic decomposition occurs with temperature above 270–280°C[16]. The sub-components of biomass respectively from which timber is composed, are variously resistant to thermal decomposition. Hemicelluloses are decomposed in the temperature range 170-240 °C. Cellulose is resistant to temperature up to 250 °C then occurs intense thermal decomposition. Thermally durable wood component is lignin, which extends until the temperature of 300-400°C[16,17]. Thermal decomposition and contents of the internal energy play one of the most important roles in the flame spread rate depending on the temperature (thermal load).

Solid carbon (as a fundamental element of biomass) reacts with atmospheric oxygen. The reaction is at the interface phase of the solid and gas. There are two types of mechanism of gaseous products formation: solid sublimate respectively melt and vaporize.[18] This process occurs without changes in chemical composition, because due to solid pyrolysis, biomass is decomposed into volatile substances (gases) and carbon residue. Due to temperature and heating change the composition to the gaseous products and the rest.

Heat transfer is based on transfer energy through vibrations of atoms where the energy from higher energy molecules (in our case, heating up the device) toward the lower energy molecules (accumulations) is accumulated. Thermal conductivity depends on temperature, weight and absolute humidity. E.g. oak and beech wood is much more conductive than spruce. Generally, hard wood is more conductive[19].

Linear Flame Spread: Linear velocity of flame propagation (equal to: Average linear velocity of flame spread) is the speed at which the flame spread in the reference direction by a specified distance per time unit. Flame spread can be regarded as constant. Generally, the rate of flame spread depends on the speed of preparation of combustible materials to burn, the physico-chemical properties mainly of the materials, storage, construction of building and ventilation conditions. Flame spread is influenced by explosion or strong winds, the effect of radiant heat, flowing hot combustion products etc[20].

Current testing methods

The following parts describe some test methods that are used to measure the speed of flame spread.

Semiquantitative test of flammability(SQTF): This test was described by Siwkem a Pellmanem in the 1986 a is mentioned by Eckhoff[21]. For testing at ambient temperature the sample is formed into a triangular shape and is located on a ceramic sample holder. At one end is approaching hot platinum wire. Apparatus used for testing at elevated temperatures is described at Fig.2. The sample is placed in a glass tube which is heated to the desired temperature. The air velocity must be maintained at 0.2 m/s.

Dust in the layer is classified by the ability to spread the fire. Ignition is achieved by using an incandescent platinum wire at a temperature of 1000⁰C or gas flame. Tested sample's dimensions was 2x4 cm. Dust sample triangular cross-section is deposited on a ceramic sample holder and it is initiated at one end.

Dusts classification based on SQTF[21]: class 1 – No self-sustained combustion, class 2 – local combustion of short duration, class 3 – local sustained combustion but no propagation, class 4 – propagation smoldering combustion, class 5 – propagation by an open flame, class 6 – explosive combustion.

Test method for flammable solids classifying by flame spread: This test method was introduced in the Czech standard, but it was repealed in 2003 without compensation. The test is described and used in the instructions laboratory practice in VSB-TU Ostrava[22] and Czech Polytechnic Univesity[23]. The time is measured in which flame transfers over the dust layer at a distance of 10 cm in the upstream oxygen. The measured value is calculated according to the rate of flame spread with respect of the rule that the velocity is equal to the track at the time.

As a tools for the measurement must be used: stems form the sample and sieve with a mesh size of 0.5 mm. Determination of flame spread rate is made using the sample granulometric state: a) with a sieve with a mesh size of 0.5 mm, b) a minimal drop 90% through a sieve with a mesh size of 0.063 mm, c) stating the sieve analysis. According to the test method there are two various measurement made always five times. As a result of the measurement the average value, standard deviation and burn rate characteristic we got. Measurements are performed in the

following two modifications dust layer height[24].

Dust layer with thickness of 5 mm: The sample was prepared in the semi-circular cross section with tickness 5 mm and length 120 mm.There are two marks at the base spaced 100 mm. Oxygen flow is set to 0.5 l.min^{-1} with an accuracy of 3 mm on the tube flowmeter. Sample holder is inserted into the tube so that the end of holder stands out from the tube. The sample is ignited and is measured the time when flame spreads from one mark to another.

Dust layer with thickness of 1 mm. The sample is sieved through sieve 0.5 mm, which is located about 1 mm above the sample holder until it fills the screen openings. The sample shall be marked instead of 100 mm away from the end of the dust layer. As in the previous procedure the sample is placed in a tube (guideline is towards the tube), the flow rate set at 0.5 l.min^{-1} and the sample is ignited at the projecting end. The

transition combustion front through a designated mark is time to achieve the burning end of the sample[25,26].

Flame spread is calculated from the measured values of time and distance for which the time is measured. Measurement uncertainty is 20% of the speed of propagation of the flame. Evaluation results are assessed verbally by the burning rate[27] (table-1).

Table-1
Flame spread assessment

The burning rate (cm.s^{-1})	Assessment
> 10	flame spreads very well
1 – 10	flame spreads well
0 – 1	flame spreads
0	the sample does not burn in the test conditions
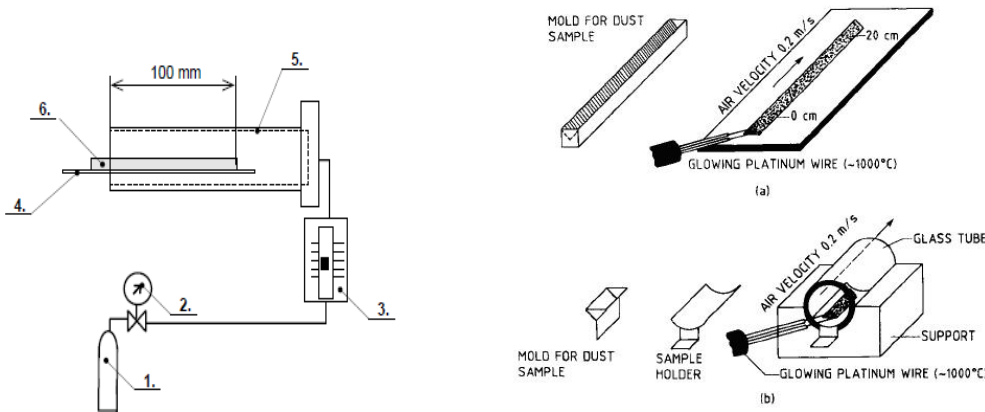
Legend: 1.-cylinder with oxygen, 2.-pressure reducing valve, 3.-flowmeter with flow controller, 4.-sample holder, 5.-quartz tube with diameter 25 mm ± 0.5 mm, 6.-sample.
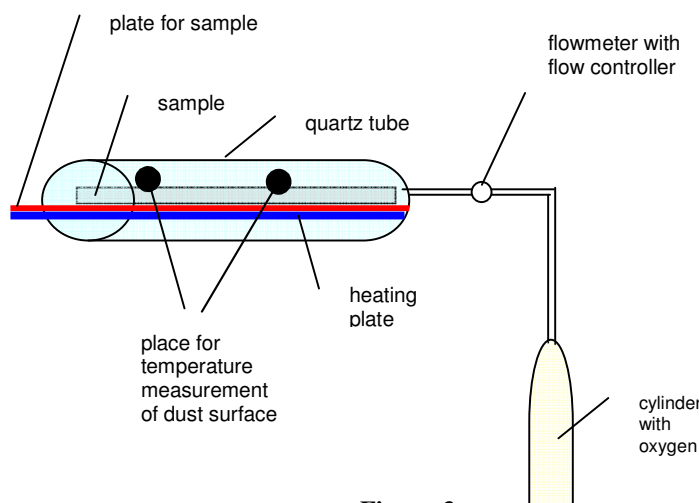
Figure-2
Apparatus[11]

Figure-3
Preliminary design of the test apparatus

Conclusion

Further focus of my work is to collect the knowledge about the influence of external conditions as humidity, temperature, oxygen concentration and internal factors as particle size, dust layer thickness on the fire safety characteristics of wooden pellet dust[28]. These characterstics are necessary for ignition risk estimation and for complete risk assasement in order to prepare fire safety regulation for pellet stocking, transport and use.

Three main topics were defined to achieve the goals.

Determination of fire safety characteristics of dust from wood pellets by standard test methods (ignition of swirled dust, ignition of dust sediment on hot surfaces, ignition and flash in the hot air furnace, flame spread by RO method, calorimetria)[29,30].

Design and implementation of test methods to determine the flame spread rate and flameless pellets dust combustion on the surface. Flame and smoldering of dust on hot surfaces in a dynamic air atmosphere need to be measured as well as horizontal flame spread rate and decay in a controlled oxidizing atmosphere.

Determination of critical conditions for the transition flameless combustion flame retardants for dust elements. Carbon oxides measurement during the thermal degradation and total heat release based on oxygen consumption during the combustion.

Experimental part of the work will deal with the design of test apparatus, based on existing test methods "Test method for classifying flammable solids by flame spread." Thermal loading of the sample is pre-designed with ceramic heating plate on which a sample is placed on. The surface temperature of the sample is monitored by a contact thermometer (figure-3). In the experimental section the following parameters will be monitored and measured: temperature of the heating plate, surface temperature of the sample, time of flame spread over the defined distance along the sample.

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