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Investigations into the influence of dustiness on dust explosions

Alexander Klippel [a,*], Marc Scheid [a], Ulrich Krause [b]

[a] *Federal Institute for Materials Research and Testing (BAM), Department 2 "Chemical Safety Engineering", Unter den Eichen 87, 12205 Berlin, Germany*
[b] *Otto-von-Guericke-University of Magdeburg, Chair of System Engineering and Plant Safety, Universitätsplatz 2, 39106 Magdeburg, Germany*

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ABSTRACT

A new safety characteristic the "dustiness" according to VDI 2263 – part 9 (Verein Deutscher Ingenieure, 2008) is investigated. Dustiness means the tendency of a dust to form clouds. The paper deals with the influence of the dustiness on vented dust explosions. In order to look into the effects of the dustiness on dust cloud formation and explosion properties experiments and simulations in a vertical dust dispersion glass tube apparatus were carried out.

Preliminary explosion experiments showed that the dustiness has an influence on the reduced explosion pressure in a vented 75 L test apparatus. Dusts with comparable $p_{\max}$ and K_{St} values and different dustiness were tested. Dusts with higher dustiness produced higher overpressures, despite comparable safety characteristics. In order to verify the results for applications in the process industries further tests with different settings are planned as well as industrial scale experiments. Characteristics of the dust such as particle size, density, specific surface area and particle shape, which influence the dispersibility, have been determined experimentally.

The Euler/Lagrange and the Euler/Euler approaches are compared for simulating an exemplary dust/air mixture. Especially sedimentation and the ability of the approaches to simulate the tendency of dust to stay airborne were investigated. The Euler/Lagrange approach is better suited for simulating local dust concentrations, particle size distributions and particle forces. It could be used to point out regions of high dust concentrations in a vessel. With the Euler/Euler method it is possible to achieve fast solutions for one specified diameter, but the simulated dust/air mixtures are always more homogenous than in reality. ANSYS CFX version 13 was used in all simulations.

1. Introduction

Dust explosion hazards can be found in a wide range of industrial branches. A dust explosion only occurs if an explosive dust/air mixture and an ignition source with a sufficient amount of energy exist at the same time. In order to evaluate whether or not an explosion hazard can occur and for the design of preventive and protective safety measures safety characteristics such as the ability to form explosive dust/air mixtures, lower explosion limit, maximum explosion pressure or K_{St} value etc. are needed. Tests for the determination of safety characteristics are usually performed with methods, which are defined in standards under more or less reproducible conditions such as strength of the ignition source, turbulence intensity and homogeneity of the dust/air mixture. For example the safety characteristics are used in empirical equations for the determination of the venting area. The empiric equations are based on industrial scale tests that were done with nearly homogenous dust/air mixtures. It is usually assumed that these conditions allow for a conservative evaluation or design.

In practice explosive dust/air mixtures occur very often due to dispersion of a dust layer, conveying of dust or filling up an enclosure. In such processes the dust cloud generated is usually not homogenous and does not spread out over the whole enclosure. Hauert, Fogt, Vogl, Wennerberg, and Radandt (1996) found that for pneumatic conveying with tangential release into silos reduced explosion pressures occur compared to those determined by the standard method as described in EN 14491 (DIN, 2012). These effects are now considered for safety measures depending on the filling method in the standard EN 14491. However, up to now the design depends on $p_{\max}$ and K_{St} value. The tendency of dusts to form dust clouds is not taken into account. To optimize the evaluation of explosion risks and the design of explosion protection measures a new safety characteristic the so-called "dustiness" (see VDI 2263 – part 9) could be useful. Dustiness means the way in which a specific dust is elutriated in an air flow and hence forms a dust cloud depending on the properties of the individual particles

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* Corresponding author. Tel.: +49 30 8104 1212.
E-mail address: alexander.klippel@bam.de (A. Klippel).

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as described by Hauert and Radandt (2009). Because the dustiness probably affects the propagation of a dust explosion, protection measures such as venting, could be optimized based on this parameter. Since the dustiness most likely has an influence on the probability of the occurrence of explosive dust/air mixtures and the expansion of such explosive atmospheres this parameter could be used for zoning of explosive atmospheres.

As a first preliminary result, six dusts of different dustiness groups were classified according to their dispersion behavior in turbulent flows. In order to evaluate the different dispersion behavior, the six dusts were dispersed with a filter plate in a 75 L apparatus and the dust concentrations were measured at two points over time. Additionally dust characteristics such as particle size and surface area, which influence the behavior of dust/air mixtures, were determined. First vented dust explosion experiments were done with six dusts for a dust concentration range between 250 g/m^3 and 2500 g/m^3, a venting area of 0.0113 m^2 and a static activation pressure of 160 mbar.

In safety engineering the use of computational fluid dynamics (cfd) is increasing as well as in many other engineering branches. For future use the possibilities to simulate dust/air mixtures with ANSYS CFX were examined. The Euler/Euler and the Euler/Lagrange approaches were compared to an analytical terminal velocity in a 2D study. Additionally simulated dust concentrations with both approaches were compared to measured dust concentrations in a 75 L vessel for an exemplary case. The Euler/Lagrange approach was used for additional 2D sensitivity studies. The influence of different particle forces, such as turbulent dispersion force, pressure gradient force and virtual mass force was investigated. The influence of different particle shape factors (in order to modify the specific surface area) on the terminal velocity of particles with 50 μm diameter and standard density (1000 kg/m^3), was investigated.

1.1. Dustiness

The measurement principle described in the VDI 2263 – part 9 allows the evaluation of the probability of the generation of dust clouds. So far the determination was done for a variety of dusts used in food, mining or metal industries as described by Hauert and Radandt (2009). With the measurement apparatus shown in Fig. 1 the safety characteristic “dustiness” can be determined. Dusts with similar dustiness are divided into dustiness groups. There are six dustiness groups (DG) from one to six (one means little tendency to stay airborne, six the opposite). The equipment consists of a sample container with a feeding system, a dust chamber, a dust concentration meter, a ring ionizer to electrostatically discharge the dust and a computer for data storage and analysis. A detailed description of the measurement procedure and the dustiness of various dusts can be found in the VDI 2263 – part 9 (Verein Deutscher Ingenieure, 2008).

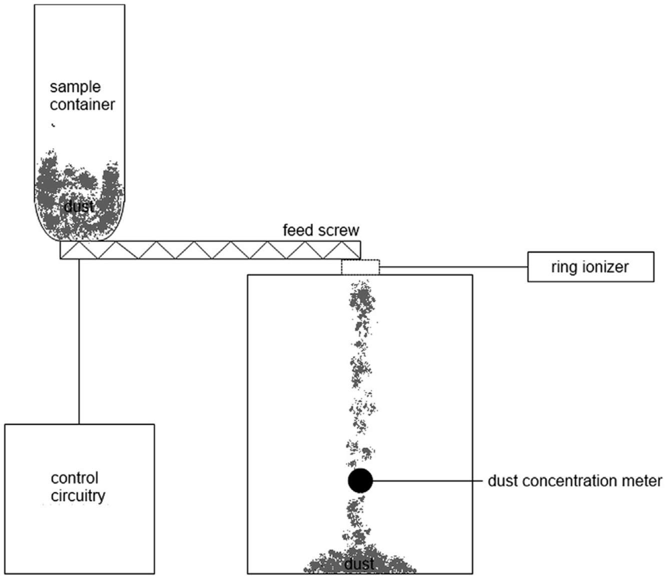

Fig. 1. Schematic of the measurement principle for the determination of the dustiness.

2. Materials, methods and experiments

A vertical dust dispersion glass tube apparatus with a 300 mm inner diameter and a volume of approximately 75 L was used for all experiments. The dust was initially layered on a filter plate with a porosity of less than 40 μm and elutriated by a controlled volume flux of air from the bottom (approx. 23 m^3/h) for two seconds in all experiments. For the explosion experiments the dust was ignited by an electrical spark (10 J) after another two seconds. Dust concentrations were measured at two different positions (37 cm and 70 cm above the filter plate) in the tube apparatus using an infrared light attenuation technique. Pressure was continuously measured during the test runs with two piezo-resistant pressure transducers one at the bottom and one in the cover (see Fig. 2).

2.1. Measurement technique

The dust concentration meters used are suitable for the measurement of dust concentrations up to approximately 1000 g/m^3. In order to measure the dust concentration the attenuation of an infrared light beam by absorption and scattering due to particles between light emitting sensor and the receiver was used. The dust concentration can be determined with the Beer–Lambert law that

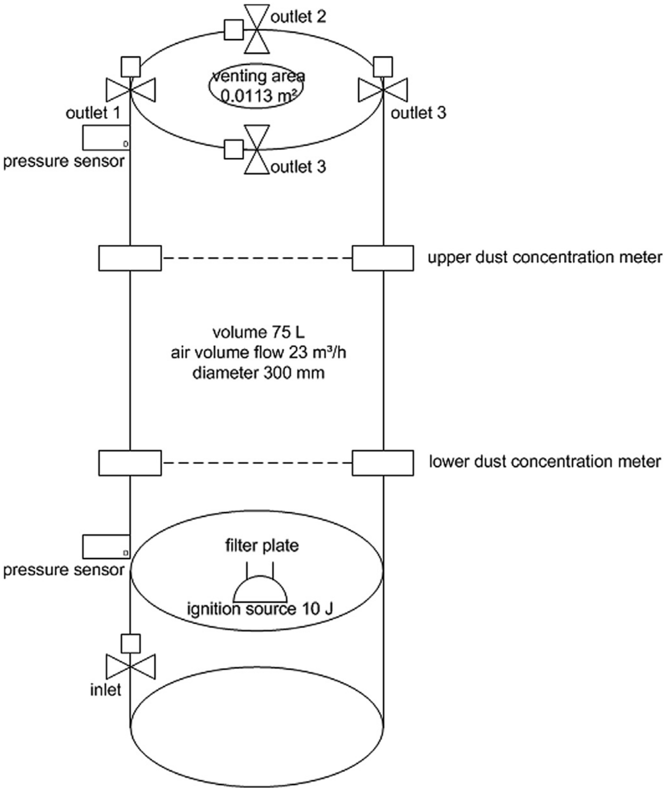

Fig. 2. vertical dust dispersion glass tube apparatus.