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Dustiness in workplace safety and explosion protection – Review and outlook

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ABSTRACT

Behavior of dust/air mixtures is very complex and difficult to predict since it depends on material properties as well as boundary conditions. Without other influences airborne particles deposit due to gravity but the time it takes for total deposition as well as easiness of resurrection depends very much on the specific dust sample and the boundary conditions. It still lacks a complete understanding of all interacting reasons and one approach is using experimentally determined characteristics, one is named dustiness.

Dustiness is the tendency of dust to form clouds and to stay airborne. Dustiness is determined with two basic principles, which are light attenuation and ratio of filled-in and measured mass. Assessment of dustiness of industrial powders has been done for a long time regarding work place safety. Dustiness is used there to determine inhalable fraction and to evaluate health risks. Lately it became interesting in dust explosion protection as well. Dustiness could be used to optimize determination of zones, adaption of venting area and/or for positioning of suppression systems.

Dustiness can be useful in many ways but is not a physical property of dusts, therefore it depends on material properties such as density, particle size distribution, shape and water content as well as boundary conditions or determination method. This makes it very difficult to compare dustiness for different techniques and apparatuses and determination method as well as results should be considered carefully. This work gives an overview of existing standards, recent research and suggests improvements to the new dustiness as proposed for dust explosion protection.

1. Dustiness

The origin of a characteristic called dustiness, the tendency of dusts to form clouds and stay airborne, is based on workplace safety. Everywhere where dusts are handled, transported and/or produced in industry such as in mining, in food industry and in energy sector there is a risk for people and facilities. Risk assessment of dusts consists of many aspects. People who work with dust need to be protected from exposure as in handling of coal dusts, food or pharmaceuticals and everyone has to be protected from too much aerosols in the environment due to traffic and industry. Furthermore most materials are combustible if sufficiently small and can lead to devastating accidents, which can harm humans as well as destroy equipment. There is a quality of dusts that helps to describe the risks named dustiness. Dustiness means the tendency of a powder to form airborne dust by a prescribed mechanical stimulus. Up to now, dustiness is used mainly for the assessment of workplace exposure regarding health safety. Dustiness testing in health care is intended to replicate dust cloud generation as found in workplaces and evaluate the exposure risk to inhalable dust fractions. This fraction is further divided into A-dust, which is the mass fraction of inhaled particles penetrating into the non-ciliate airways and E-dust or respirable dust, which is the total mass inhaled through mouth and nose (Hamelmann and Schmidt, Messverfahren zur Bestimmung des Staubungsvermögens von dispersen Pulvern, 2002). Common problems are coal handling operations (conveying, discharging, filling, weighing, sacking) as well as exposure to paints and coatings.

In dust explosion protection the possibilities of using dustiness are an actual field of research. For example investigations are done in order to adapt the necessary venting area depending on dustiness (Klippel et al., 2013). Further applications can be the

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determination of zones of explosive atmosphere (20, 21, 22) as well as positioning of suppression systems inside a vessel depending on the tendency of dusts to get dispersed.

Since dustiness is not a physical property of the material there are many influences on dustiness, see Fig. 1. Dustiness depends on the material properties as well as on the determination method or boundary conditions.

For determination of dustiness as a non-physical property such as density a method as well as a evaluation have to be defined. The two main measurement techniques for determination of dustiness are:

- light attenuation techniques where dust concentration is measured as function of time with the ratio of emitted light intensity to received light
- and ratio of sample mass to filled-in mass.

The second part is to standardize measurement procedure and the calculation of dustiness.

In order to use dustiness after determination it is important to relate the method to the industrial process. Therefore it is necessary to choose or develop a suitable method. Fig. 2 shows a simplified schematic of choosing a suitable approach. First it is important to select a measurement method, which usually are light attenuation or gravimetric measurement but some special cases such as tribo-electric or radiometric measurement (Stiess, 2009). Light attenuation is suitable if knowledge of dust concentration as a function of time is desired. For assessment of dust deposition or mass and size fractions at certain points gravimetric measurement should be used.

After choosing the measurement technique the other boundary conditions should be chosen according to the desired result. Is continuous measurement necessary? Need for external forces such as countercurrent or rotational forces. Another important point is dust injection or conveying, for example single drop or continuous drop, injection with pressurized air and elutriating of deposited dust. Even if a specific standard is recommended it is useful to evaluate whether the determined dustiness is suitable for the problem at hand. The European standard EN 15051 (DIN, 2011a, b, c) gives a guideline how to perform a “test of equivalence” for new or non-standardized devices, even if transferability cannot be achieved, it might be useful to see where differences are compared to standardized tests. For any dustiness regarding workplace exposure of dust it is recommended according to Hamelmann et al. (Hamelmann and Schmidt, Methods of Estimating the Dustiness of Industrial Powders, 2003) and Bach et al. (Bach et al., 2013) to evaluate respirable fractions as defined by the EN 481 (DIN, 1993).

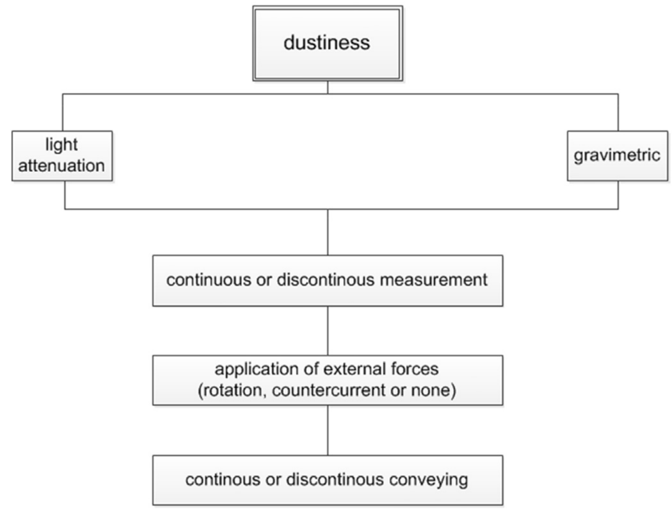

Fig. 2. Choosing a suitable dustiness determination approach (see (Hamelmann and Schmidt, Methods of Estimating the Dustiness of Industrial Powders, 2003) as well).

2. Determination methods and current standards

The somewhat elastic term dust means solid particles with diameters below 500 μm in the following. Additionally, when speaking of workplace safety, a further division is made into respirable fraction with particles smaller than 100 μm that can be inhaled via mouth and nose and alveolar fraction with particles smaller than 10 μm. In explosion protection the dust is assumed to be combustible as well.

2.1. Dustiness in workplace safety

The origins of dustiness are based on workplace safety. In order to protect people when transporting, handling or working with dusts from exposure to inhalable particles several methods were created over the decades. Already in 1939 dustiness could be determined according to an in 1980 withdrawn standard ANSI/ASTM D547-41 (ANSI, 1980 (withdrawn 1986)) “Test Method for Index of Dustiness of Coal and Coke”. The standard was used to determine dustiness of coal products. Up to now determination of dustiness and workplace safety have constantly been improved. The European standard EN 15051 part 1–3 (DIN, 2011a, b, c), (DIN, 2011a, b, c) and (DIN, 2011a, b, c) gives information on measurement of the dustiness of bulk materials with requirements and choice of test methods along with some standardized test devices. In combination with evaluation of the respirable mass fractions according to DIN EN 481 (DIN, 1993) the European standard EN

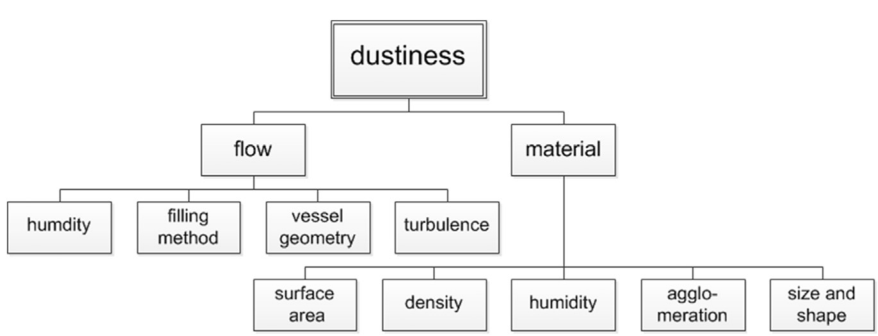

Fig. 1. Influences on dustiness.