DETERMINATION OF THE MINIMUM IGNITION ENERGY ON DIFFERENT DEVICES

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Research article

Abstract: This article focuses on determination of the minimum ignition energy of dust. For the measurement of the minimum ignition energy of dust are available device from different manufacturers. In this article, the comparison device from three manufacturers - Chilworth, Kühner and Anko are executed. For the experimental measurement of the minimum minimum ignition energy was chosen 5 dust samples so that they are represented sample of organic dust, synthetic organic dust and coal dust. The article briefly introduces each apparatus for determining the minimum ignition energy and there is a comparison of the results obtained with individual devices. Finally, it is an assessment the results obtained and used test equipment.

Keywords: Dust, explosion, Hartmann tube, minimum ignition energy.

Introduction

Prevention of dust explosion in industries manufacturing or handling combustible powder or dust is a major challenge (Eckhoff, 2003). All flammable materials in solid state, metals included, that are dispersed in the air in a form of a cloud could form the explosive atmosphere.

Determination of minimum ignition energy (MIE) of dust-air mixture is very suitable for electrostatic dust ignition risk assessment. Presence of strong ignition source is one of the conditions. Hartmann tube is used for measurement of minimum ignition energy. Minimum ignition energy of dust cloud is used for determination of the smallest amount of energy in a form of capacitive spark which causes ignition of dust cloud. The device is used mainly for probability assessment of ignition of dust during its treatment and manipulation. Experimental method requires sparks of various known energies that are discharging in a dust cloud with known energy. The aim is to find the easiest combustible dust concentration.

For measurement of minimum ignition energy, Hartmann tube or modified Hartmann tube could be used. In (Janes et. al, 2003), results of MIE measured on Hartmann tube and modified Hartmann tube are compared and the conclusions say that modified Hartmann tube, particular MIKE 3, provides the same or lower values than Hartmann tube.

The aim of this paper is to compare the results of MIE measured at three types of devices made by various producers: MIKE 3 by Kühner, MIE II by Chilworth Technology Limited and Apparatus for determination of minimum ignition energy of a dust/air mixtures by ANKO.

Materials and Methods

Experimental equipment

Experimental testing was carried out in three institutions which keep the devices for minimum ignition energy made by various producers.

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The device owned by this institute is made by Adolf Kühner AG Company. The device is marked as a Minimum Ignition Energy Apparatus (MIKE 3) and it is shown in Fig. 1.

Fig. 1 Minimum Ignition Energy Apparatus (MIKE 3) (Kühner safety, 2015)

Dispersion and ignition was performed in a glass tube with a volume of 1.2 L. Dust is dispersed by compressed air (7 bar) with the help of a nozzle of a mushroom shape. Electrodes of diameter 2.0 mm were used and a gap between conical peak should be at least 6 mm. Measurement could be performed with electrical inertia of 0 or 1 mH. Delays between dispersion and spark-over are usually set from 60 ms to 180 ms with steps of 30 ms.

MIKE 3 could work with one of following circuits:

- Starting with use of high-voltage relay and system of two electrodes. This circuit is used for low energies (1 and 3 mJ). It is described more detailed in Appendix A2 of standard EN 13821.
- Starting by electrode motion with use of system of two electrodes. This circuit operates for high energies (10, 30, 100, 300 and 1000 mJ). It is described more detailed in Appendix A3 of standard EN 13821 (Kühner safety, 2015).

OVGU Otto-von-Guericke Universität Fakultät für Verfahrens- und Systemtechnik Institut für Anlagen- und Umwelttechnik, Magdeburg, Germany

MINIMUM IGNITION ENERGY OF A POWDER TEST APPARATUS (MIE III) is a name of the device made by Chilworth Technology Limited and owned by the university in Magdeburg. The device is presented in Fig. 2.

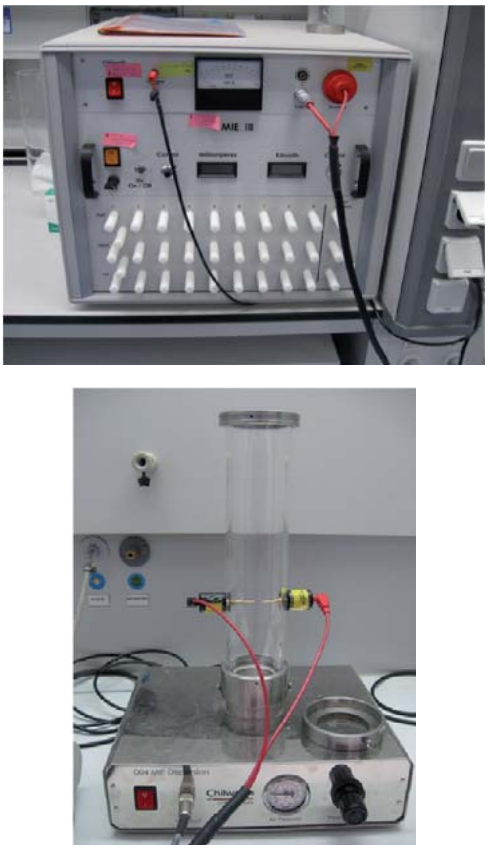

Fig. 2 Minimum Ignition Energy of a Powder Test Apparatus (MIE III)

Dispersion and ignition was performed in an acrylic tube with a volume of 1.0 L. Dust is dispersed by compressed air (7 bar) with the help of an adjustable nozzle of a mushroom shape. A gap between conical peak should be 6 mm. Measurement is based on formation of electric spark of known energy that is discharged through known density of dust cloud.

The variables that influence the energy discharge follow:

- total chosen capacity;
- distance between electrodes (6 mm, but it could be reduced);
- voltage measurements in discharge time according to records (1 Vdc on a calibrated fluke = 10 kV) (Dekra, 2012).

GIG - Central Mining Institute Experimental Mine "Barbara", Mikołów, Poland

This institute keeps the device called *MINOR 1*, made by ANKO Company and illustrated in Fig. 3. As the dispersion system and pneumatic part are separated, dust dispersion pressure can be adjusted in range of 0 to 7 bar. This allows to choose optimal dispersion conditions. Sample is dispersed in 1.2 L glass tube by mushroom type nozzle. Time delay between dispersion and spark-over can be set in range of 60 to 1000 ms, with 10 ms step. As a control parameter actual delay time is measured.

Fig. 3 Apparatus for determination of minimum ignition energy of a dust/air mixtures (Anko, 2015)

Experimental materials and methods

Five dust samples were chosen for experimental measurement of MIE according to categories mentioned in EN 13821 except metal dust. The samples were chosen from following categories: natural organic dust, synthetic organic dust and coal dust. These dusts were particularly used: potato starch, powder paint, toner, torula yeast and black coal which are shown in Fig. 4.

The specimens were dried and their humidity and powder density were determined. The results are shown in Tab. 1. Then TGA analysis was executed and its results are introduced in Tab. 2. The specimens were prepared to the grain size smaller than 0.040 mm except the powder paint sample that was used in original condition. Results of grain size analysis of powder colour are listed in Tab. 3 and Fig. 5.

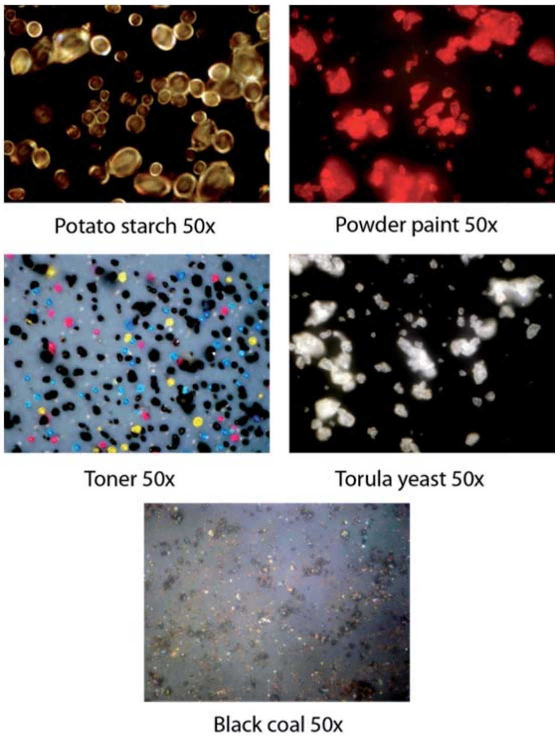

Fig. 4 Pictures of tested samples after enlargement

Tab. 1 Humidity and powder density of tested samples

Sample	Humidity [%]	Powder density [kg/m^3]
Potato starch	1.34	770
Powder paint	0.86	590
Toner	1.19	500
Torula yeast	1.91	560
Black coal	0.89	500

Tab. 2 Results of TGA analyses

Sample	Humidity [%]	Volatile constituent [%]	Volatile constituent in the dry matter [%]	ASH [%]	Ash in the dry matter [%]
Potato starch	2.22	91.36	93.43	0.41	0.42
Powder paint	0.67	81.18	81.73	21.05	21.19
Toner	0.11	62.62	62.69	38.84	38.88
Torula yeast	3.24	75.59	78.12	7.62	7.88
Black coal	0.97	27.87	28.14	5.83	5.88

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Tab. 3 Grain size analysis - Powder paint

Granulometric state	**P**
Sieve [mm]	**Oversize [mass %]**
0.025	99.34
0.032	81.7
0.040	67.15
0.063	20.87
0.075	18.51
0.106	5.14
0.125	2.11
Middle size of a grain [mm]	**0.048**

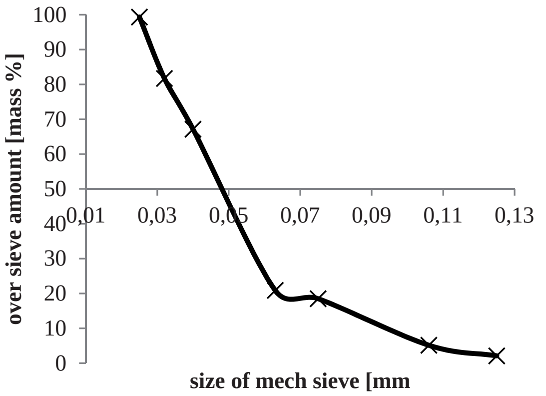

Fig. 5 Grain size analysis - Powder paint

Experimental procedure

Each series of tests is carried out for a given concentration of dust in air and a given delay between dust dispersion and spark-over. Two delays were tested: 120 ms and 150 ms. The exception is the device by Chilworth where delay is not set.

The test procedure was performed according to EN 13821. 10 consecutive unsuccessful ignition attempts were required to confirm a non-ignition result for given concentration and energy. Moreover, dust was removed after a maximum number of five non-ignition attempts. At our measurements, the sample was changed after 3, 3 and 4 unsuccessful experiments.

The tests began with the highest of ignition energy value 1000 mJ and the delay between dust dispersion and spark-over set for the first series was 120 ms, for the second series 150 ms. It was also necessary to set a definite value of average dust concentration. The tests began with an average concentration close to 750 g/m^3. Circuit inductance was kept constant during the complete course of the procedure. Tests were carried out with an inductance of 1 mH only.

The recommendations for results interpretation of MIE are based on energy levels available for the device MIKE3. According to routine of INERIS (Ineris, 2015), the results could be sorted as follows:

- MIE > 1000 mJ: the sample almost insensitive to electrostatic ignition,
- 300 mJ < MIE < 1000 mJ, 100 mJ < MIE < 300 mJ and 30 mJ < MIE < 100 mJ: the sample sensitive to electrostatic ignition,
- 10 mJ < MIE < 30 mJ and 3 mJ < MIE < 10 mJ: the sample very sensitive to electrostatic ignition,
- 1 mJ < MIE < 3 mJ and MIE < 1 mJ: the sample extremely sensitive to electrostatic ignition, (James et al., 2003).

Results

The results of experimental measurements of minimum ignition energy are given in a form of graphs in following Figures. The x-axis represents the samples masses in mg and the y-axis presents the energy values in mJ. The results for dust sample of potato starch is in Fig. 6, in Fig. 7 for sample of powder paint, in Fig. 8 for dust sample of toner, in Fig. 9 for dust sample of torula yeast and in Fig. 10 for dust sample of black coal.

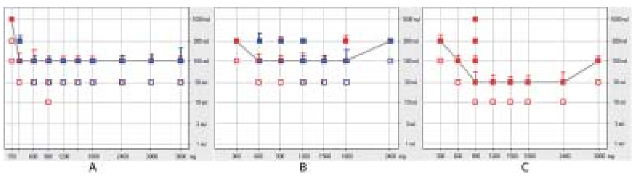

Fig. 6 MIE Potato starch A - VVUÚ a.s.; B - GIG; C - OVGU

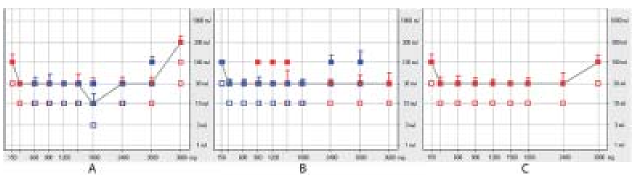

Fig. 7 MIE Powder paint A - VVUÚ a.s.; B - GIG; C - OVGU

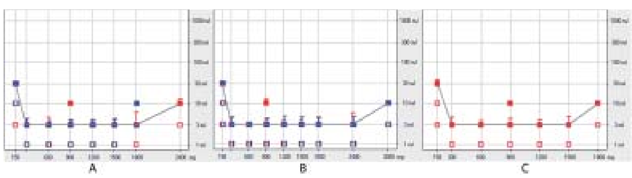

Fig. 8 MIE Toner A - VVUÚ a.s.; B - GIG; C - OVGU

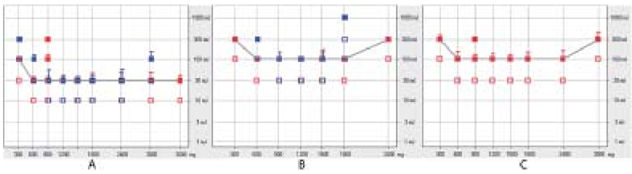

Fig. 9 MIE Torula yeast A - VVUÚ a.s.; B - GIG; C - OVGU

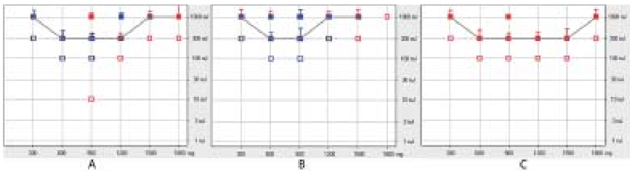

Fig. 10 MIE Black coal A - VVUÚ a.s.; B - GIG; C - OVGU

Tab. 4 summarizes the statistical values of minimum ignition energy for particular samples of dust and for particular devices. The energy levels for classed of tested samples on the basis of measurement results are introduced and statistical values of MIE are listed for comparison of results measured at particular devices.

Discussion

Within the experimental measurements, minimum ignition energy was measured at 5 different dust samples. Measurements were performed on three types of devices for determining the minimum ignition energy from different manufacturers of these devices.

Sample of potato starch

Comparing energy levels for samples classification according to results of MIE, it could be stated that potato starch sample is placed twice (Kühner and Anko devices) in the class of 30 mJ < MIE < 100 mJ with evaluation "sample sensitive to electrostatic ignition". In the case of Chilworth device, the sample is classed to 10 mJ < MIE < 30 mJ as "sample very sensitive to electrostatic ignition".

Sample of powder paint

Comparing energy levels for samples classification according to results of MIE, it could be stated that powder paint sample is placed twice (Chilworth and Anko devices) in the class of

Tab. 4 Results of experimental measurements of minimum ignition energy

Sample	**VVUÚ a.s.**	**GIG**	**OVGU**
Potato starch	30 mJ < MIE < 100 mJ sample sensitive to electrostatic ignition **Es (mJ)** 37 (120 ms) 38 (150 ms)	30 mJ < MIE < 100 mJ sample sensitive to electrostatic ignition **Es (mJ)** 50 (120 ms) 60 (150 ms)	10 mJ < MIE < 30 mJ sample very sensitive to electrostatic ignition **Es (mJ)** 15 (-)
Powder paint	3 mJ < MIE < 10 mJ sample very sensitive to electrostatic ignition **Es (mJ)** 13 (120 ms) 8 (150 ms)	10 mJ < MIE < 30 mJ sample very sensitive to electrostatic ignition **Es (mJ)** 15 (120 ms) 16 (150 ms)	10 mJ < MIE < 30 mJ sample very sensitive to electrostatic ignition **Es (mJ)** 14 (-)
Toner	1 mJ < MIE < 3 mJ sample extremely sensitive to electrostatic ignition **Es (mJ)** 1.4 (120 ms) 1.4 (150 ms)	1 mJ < MIE < 3 mJ sample extremely sensitive to electrostatic ignition **Es (mJ)** 1.4 (120 ms) 1.4 (150 ms)	1 mJ < MIE < 3 mJ sample extremely sensitive to electrostatic ignition **Es (mJ)** 1,5 (-)
Torula yeast	10 mJ < MIE < 30 mJ sample very sensitive to electrostatic ignition **Es (mJ)** 12 (120 ms) 15 (150 ms)	30 mJ < MIE < 100 mJ sample sensitive to electrostatic ignition **Es (mJ)** 47 (120 ms) 55 (150 ms)	30 mJ < MIE < 100 mJ sample sensitive to electrostatic ignition **Es (mJ)** 45 (-)
Black coal	100 mJ < MIE < 300 mJ sample sensitive to electrostatic ignition **Es (mJ)** 190 (120 ms) 190 (150 ms)	100 mJ < MIE < 300 mJ sample sensitive to electrostatic ignition **Es (mJ)** 420 (120 ms) 190 (150 ms)	100 mJ < MIE < 300 mJ sample sensitive to electrostatic ignition **Es (mJ)** 160 (-)

10 mJ < MIE < 30 mJ with evaluation “sample very sensitive to electrostatic ignition”. In the case of Kühner device, the sample is classed to 3 mJ < MIE < 10 mJ as “sample very sensitive to electrostatic ignition”.

Sample of toner

Comparing energy levels for samples classification according to results of MIE, it could be stated that toner sample is placed for all three cases in the class of 1 mJ < MIE < 3 mJ with evaluation “sample extremely sensitive to electrostatic ignition”.

Sample of torula yeast

Comparing energy levels for samples classification according to results of MIE, it could be stated that torula yeast sample is placed twice (Chilworth and Anko devices) in the class of 30 mJ < MIE < 100 mJ with evaluation “sample sensitive to electrostatic ignition”. In the case of Kühner device, the sample is classed to 10 mJ <MIE < 30 mJ as “sample very sensitive to electrostatic ignition”.

Sample of black coal

Comparing energy levels for samples classification according to results of MIE, it could be stated that black coal sample is placed for all three cases in the class of 100 mJ < MIE < 300 mJ with evaluation “sample sensitive to electrostatic ignition”.

Measurements were performed with different devices therefore the following paragraphs try to compare the measurements according to subjective feelings.

Device by Kühner

Subjectively, measuring with this device could be evaluated as the best, mainly for handling with it using user-friendly software. Values of energies and samples weights are entered using understandable and well-arranged software interface that is supplied to the device and that also includes the evaluation and measurements records. Glass tube is worse for cleaning, though. Measurement with this device was the fastest.

Device by Chilworth

Measurements using this device could be evaluated as the most difficult due to entering of spark energy. Operator has to set manually the condensers with required capacity and to set the voltage value that indicates the spark energy according to the conversion table. After experiment, real voltage in time of spark appearance should be read from the record instrument and find the real spark energy using the conversion table. It is more demanding for operators without experience with such a device. On the other side, it is easy to demount the plastic tube and clean it comfortably. Operators should record the tested concentrations, energies and the evaluation on their own.

Device by Anko

Compare to devices mentioned above, this equipment could be evaluated as average. Required energy data are entered right at the operator desk but that particular device could not record or evaluate measured data so the operators should record it on their own. Cleaning of the tube is the best at this device as the glass tube is demounted easily.

Conclusion

On the basis of measured values it could be stated that the results are comparable for the samples of toner and black coal for all three testing devices. In the case of the samples of torula yeast and powder paint, the values of MIE obtained by the Kühner device are lower and two other devices show comparable results. For potato starch, the Chilworth device measured the lowest value and two other devices provide comparable values.

From the user´s point of view, the device by Kühner could be evaluated as the best; time-consuming of measurement is the least of all tested devices.

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