Dust Clouds as an Explosion Risk
— Its Characteristics

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Abstract: One of the main problems to assess the risk of dust explosions is to identify the behaviour of dust clouds. Methods to identify the characteristics of dust clouds and a conveying system designed to investigate the characteristics of dust clouds were developed and a new concept of dust formation factor SN is introduced.
Keywords: Dust cloud, Characteristics, RMS turbulence, Dust formation factor S_N

1. Measurements of dust cloud characteristics inside equipment

One of the problems to assess the risk of dust explosions is to identify the behaviour of dust clouds. Therefore we developed methods to identify this and designed a conveying system to investigate this.

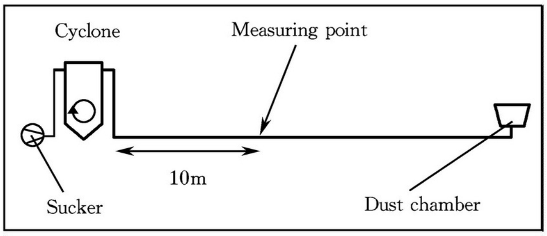

Fig.1 The principle picture of this pneumatic conveying

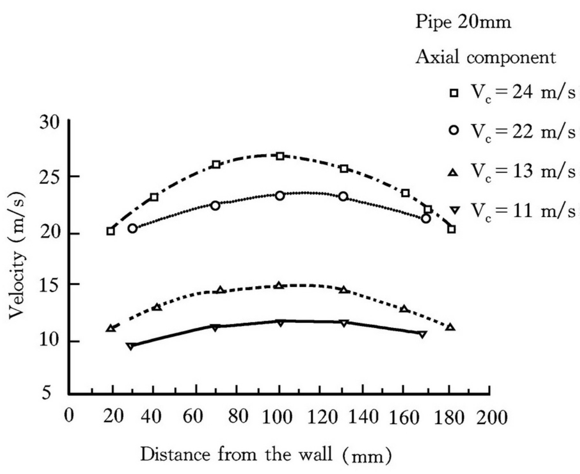

Fig.2 Particle velocity distribution under different conveying velocities

Particle velocity distribution in a pipe under different conveying velocities is demonstrated in the next picture. The turbulence in the pipe has great influence on the violence of an explosion because it causes an acceleration of the flame and therefore high pressure. Fig.3 shows the RMS turbulence velocity in the pipe under different conveying velocities. Important information is the relationship between RMS turbulence velocity and conveying velocity. In the connected cyclone we found for RMS turbulence velocity in a cyclone under different conveying velocities the following results (Fig.5).

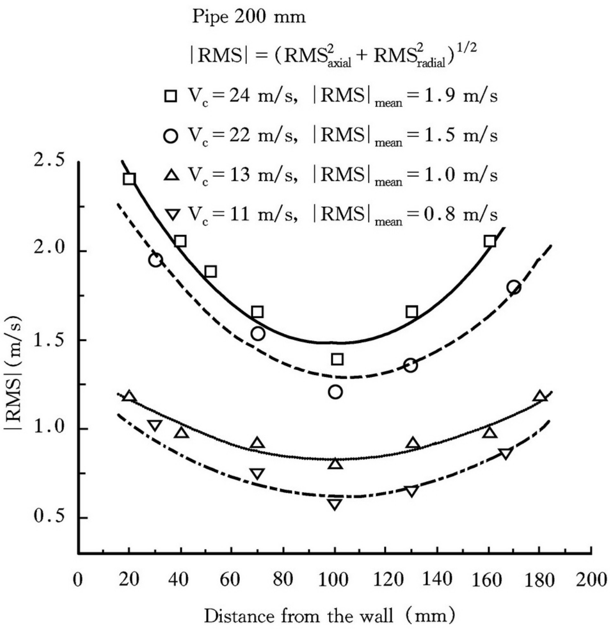

Fig.3 The RMS turbulence velocity under different conveying velocities

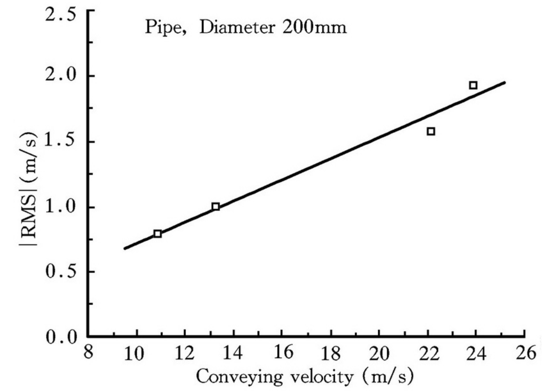

Fig.4 The relationship between RMS turbulence velocity and conveying velocity

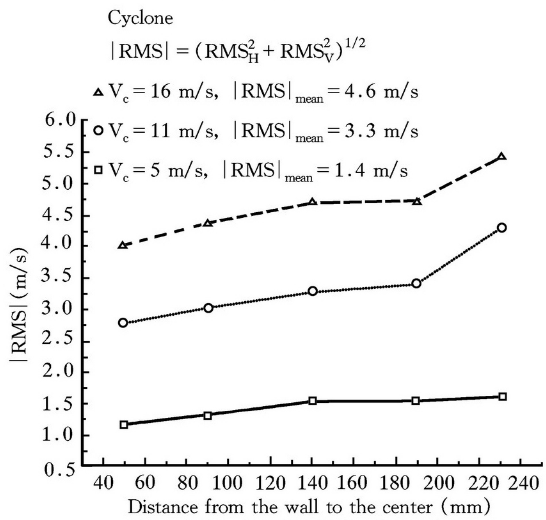

Fig.5 RMS turbulence velocity in a cyclone under different conveying velocities

2. Determination of a characteristic in respect to the ability of dust cloud formation of combustible bulk materials

It is known that the violence of a dust explosion depends not only on the thermal characteristics of the kind of dust but also on the ability to create a dust cloud. Therefore we developed a method to identify to the ability of dust cloud formation of combustible bulk materials.

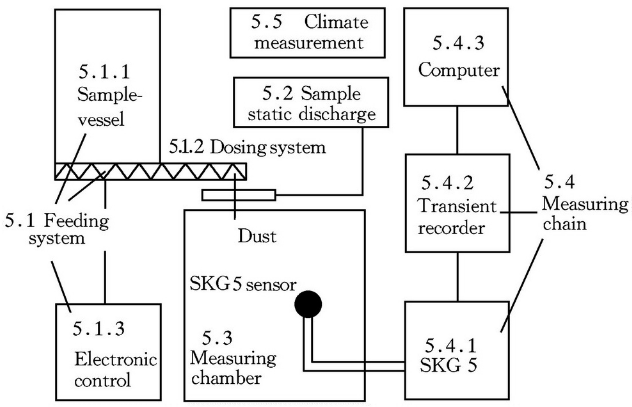

Fig.6 The schematic test set-up

The measuring set-up consists of a dosing and feeding system, a measuring chamber, the SKG 5 dust concentration meter, a transient recorder and a computer with evaluation software.

3. Dust concentration meter SKG 5

For sensing the dust concentration inside the measuring chamber during the measurement. Installed in the measuring head of the SKG 5 is a LASER diode which emits an infrared light beam (1 μm) through the examined volume to a receiver opposite the measuring head. The dust concentration is obtained from the light absorption on the basis of the Lambert-Beer law.

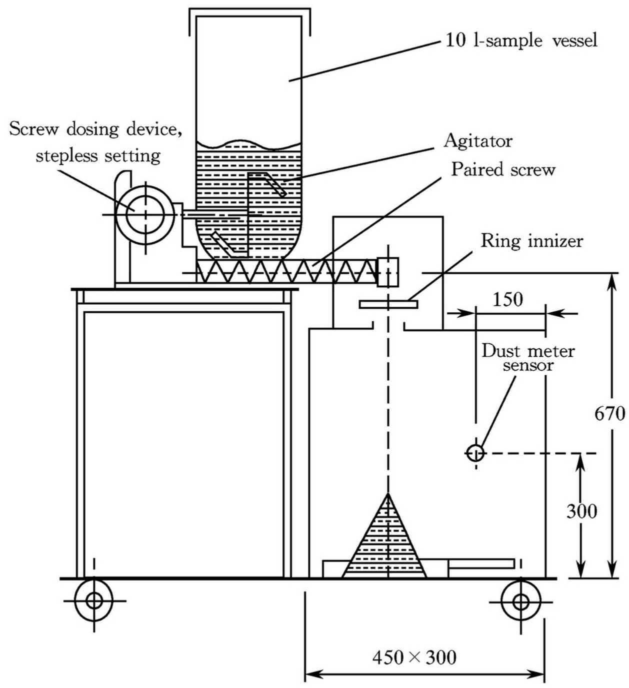

Fig.7 The mechanical test set-up

3.1 Test procedure

3.1.1 Sample quantity

The required sample quantity is obtained from the falling volume flow (1 dm^3/min), the feeding time of 5 minutes and an addition for sufficient filling of the dosing device to obtain at least 6 dm^3. As a rule, at least 4 kg sample material is needed.

3.1.2 Sample treatment

To obtain realistic results, the test should be made with sample material as delivered, i.e., without treatment; the room temperature must be within 20℃ ± 5℃ and the relative humidity between 30% ± 20%. The sample should be tested as quickly as possible after arrival of the material. If this is not possible, the sample must be stored protected from the entry of air and moisture. Thus, the sample is not normally treated unless the measurement cannot be made with the untreated sample material, in which case the type of treatment must be agreed.

In addition to the dust concentration, the moisture and the bulk density of the material as delivered are also determined and recorded in the test report. Frequently, the particle size distribution must also be determined as part of the order.

3.1.3 Recording of the calibration curve for the SKG 5

In the laboratory, a defined amount of the dust sample is dispersed in a special light-transmitting vessel containing a defined volume of ethanol. The attenuation of the light penetrating the vessel is measured by the SKG 5. The attenuation of the light (in mV) is noted, together with the dust concentration in the vessel (in g/m^3). This procedure is repeated several times and each time the dust concentration in the vessel is increased. In this way, a calibration curve for the dust that is to be examined is obtained, and the light attenuation measured in the chamber can be assigned to the corresponding dust concentration $c(t)$.

3.1.4 Measuring process

The sample material as delivered and without dust loss is filled in the sample container. A scoop or shovel may be used for filling the material. The container is filled with as much sample material as is required to maintain a sufficient filling of the container after completion of an individual measurement.

The motor speed of the dosing screw is set to 500 rpm corresponding to a volume flow rate of approximately 1 dm^3/min. The product moisture, relative humidity of the air and the temperature in the room are measured. The measuring heads of the SKG 5 are adjusted along their optical axis with a gauge and set to a measuring distance of 200 mm. The measurement commences with starting the instruments in the following order:

Dust concentration meter SKG 5.

Ring ionizer. Transient recorder with computer.

Stop watch and dosing device.

The dosing device is switched off after five minutes feeding and the sedimentation behaviour of the swirled-up dust measured with the instruments in the measuring chain for another 350 seconds. Then the measuring data is transmitted from the transient recorder to the computer, where it is stored permanently. The dust transported in the measuring chamber during the measurement is removed, weighed and the weight recorded. After this, the measuring chamber is cleaned.

3.1.5 Evaluation

With reference to the calibration curve of the product, the light attenuation curves stored in the computer are converted to dust concentration data across time. Then the evaluation program calculates the appropriate dust formation factor SN from the three individual measurements. Finally, the mean of the results of the individual measurements is calculated and assigned to the respective dust formation class.

3.2 Sample Calibration Curve for SKG5

Fig. 8 shows a calibration curve for rapeseed filter dust with coefficients $B_1 = -1042$, $B_2 = -0.005439$, and $B_3 = 1038$.

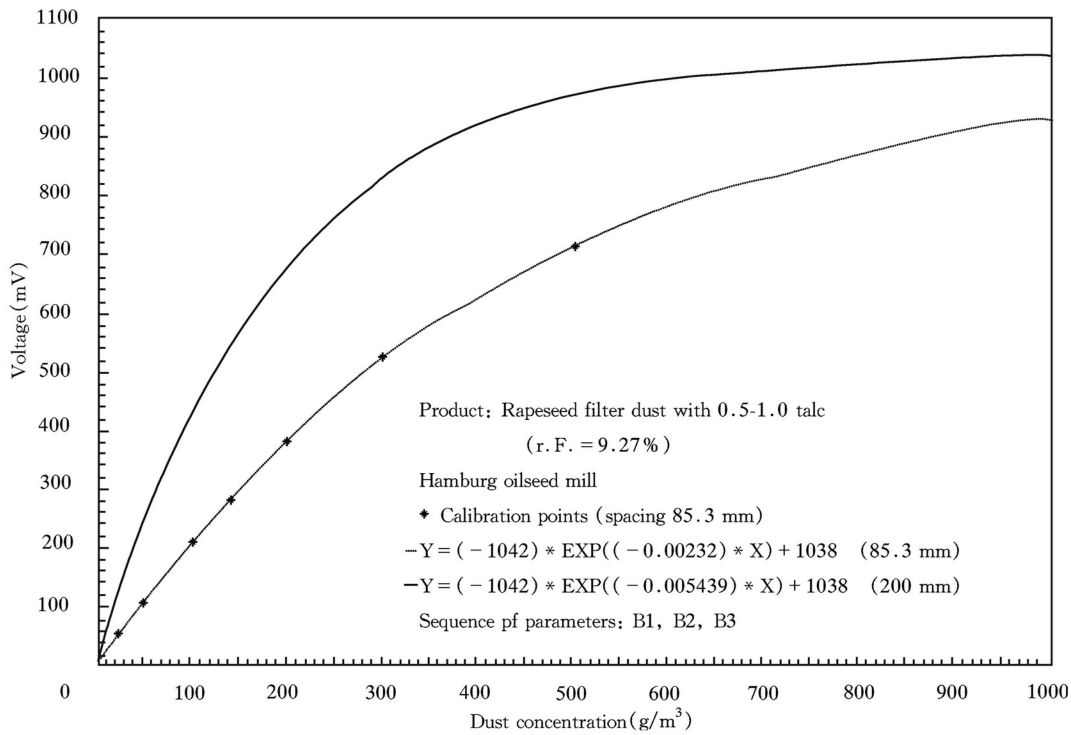

Fig. 8 A calibration curve

4. Dust formation factor S_N

The dust factor S_N expresses the mean dust concentration of the N dust relative to a time span of 650 seconds. This factor is expressed by the following equation:

$$S_N = \frac{1}{650} \cdot \int_0^{650} c(t)\mathrm{d}t$$

With $c(t)$ the dust concentration measured in the measuring cylinder of the meter across time (Fig.9).

5. Dust formation classification

The number characterizing the size class of dust formation factor S_N. Tab.1 list he dust formation factor is divided in six dust formation classes.

Tab.2 below contains the dust formation data obtained with the method of this norm, the appropriate standard deviation and dust formation classes for 12 products.

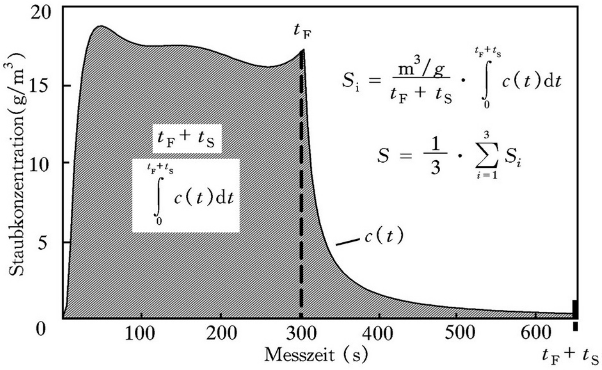

Fig.9 The dust concentration measured in the measuring cylinder of the meter across time

6. Conclusion

A new concept of dust formation factor S_N is introduced. It is a new method to characterize dust cloud and the method could be used to better analyze dust explosion risk.

Ta.1 Dust formation classification

Dust formation class	1	2	3	4	5	6
Dust formation factor/(g/m³)	0-0.99	1-3.99	4-6.99	7-9.99	10-49.99	≥50
Sample	Wrinkled pea starch	Corn starch (wet)	Corn starch (dry)	Corn starch (dry)	Wheat flour (wet)	Wheat flour (dry)
Relative product humidity/%	9.9	9.3	3.8	2.4	11	1.4
Room tem-temperature/℃	22.7	23.0	23.5	24.3	24.1	21.9
Relative humidity/%	34.6	41.0	41.0	28.6	34.0	30.6
No. of tests	3	3	3	3	3	3
Measuring time/s	650	650	650	650	650	650
Flow rate/(l/min)	1	1	1	1	1	1
Mean dust formation factor S_N/(g/m³)	64.8	5.6	5.9	6.5	0.1	2.2
Relative standard deviation/%	3.0	2.7	6.1	3.1	43.3	11.3
Dust formation class	6	3	3	3	1	2

Tab.2 Dust formation classification

Probe	Wheat starch	Mold powder starch	Malt dust	Potato powder	Rapeseed filter dust	Crushed soybean filter dust
Relative product humidity/%	9.9	5.1	7.8	11.1	9.3	6.5
Room temperature/℃	22.4	22.9	22.7	23.2	23.5	22.5
Relative humidity/%	31.9	25.0	31.7	41.2	21.1	21.1
No. of tests	3	3	3	3	3	3
Measuring time/s	650	650	650	650	650	650
Flow rate/(l/min)	1	1	1	1	1	1
Mean dust formation factor S_N/(g/m³)	10.8	0.7	8.1	23.5	1.2	3.3
Relative standard deviation/%	9.2	14.3	6.4	0.2	8.3	3.0
Dust formation class	5	1	4	5	2	2