1 General information

The dust formation tendency (dustiness) of a dispersed solid can be understood as the property (in the meaning of a sum parameter) of releasing a particle fraction of a special quantity and size distribution in a gaseous environment given certain handling – at least for a short time.

In general, this release of dust is undesirable because it might result in material loss, is often associated with personnel being exposed to it and may cause environmental pollution. The dustiness might change along the process path, for example, through comminution, agglomeration, classification or mixing of the solids involved.

Within the scope of the DFG priority program 1679 "Dynamic simulation of interconnected solids processes", prognosis functions of the dust formation tendency comparable to the testing methods single drop, rotating drum and UNC dustiness tester were developed. These forecasting functions can be applied to the finished product of the simulation process. More details on this topic can be found in [1].

2 Single drop

To simulate the filling of particles a single drop testing method is used. The measurement is performed by allowing a powder sample (30 g) to fall through a tube (0.5 m) into a measurement chamber. Here the powder particles collide and sediment on the chamber bottom. By logging the extinction of two laser light sources the time dependent development of dust emission can be monitored. In case of the implemented forecast functions two attenuations of light are predicted – maximum attenuation of light and the light attenuation, which is recorded 30s after the drop of the sample (cf. table 1).

The dust release number S_{SD} based on the following equation:

$$S_{SD} = E_{MAX} + E_{30}$$

Table 1. Prediction functions under different environmental conditions

Environmental conditions	Forecasting functions
20% relative humidity	$E_{MAX} = -14.32 + 30.95 \cdot \log(K_{SD})$ $E_{30} = -11.802 + 21.491 \cdot \log(K_{SD})$
50% relative humidity	$E_{MAX} = -19.19 + 29.14 \cdot \log(K_{SD})$ $E_{30} = -14.10 + 17.79 \cdot \log(K_{SD})$
80% relative humidity	$E_{MAX} = -20.00 + 29.30 \cdot \log(K_{SD})$ $E_{30} = -14.04 + 17.33 \cdot \log(K_{SD})$
Low vacuum	$E_{MAX} = -14.76 + 24.71 \cdot \log(K_{SD})$ $E_{30} = -8.88 + 14.91 \cdot \log(K_{SD})$

Single drop specific calculation factor:

$$K_{SD} = \frac{2}{3} \cdot \frac{\varepsilon}{1-\varepsilon} \cdot d_{32} \cdot \frac{x_{50.2} - x_{10,2}}{x_{10,2}} \cdot \frac{1}{\mu m},$$

where

- ε – bulk porosity
- d_{32} – Sauter diameter

3 Rotating drum

To simulate mixing and filling of powders the rotating drum testing method according to DIN 55992-1 can be used. A powder sample (100 g) is placed in the rotating drum of the apparatus. By rotation the sample is simultaneously mixed and dropped. The mechanical stress releases particles from the sample. An axially induced air flow will transport the released particles out of the rotating drum onto a filter with defined porosity. The amount of released and transported particles is determined gravimetrically after a sampling time of 5 minutes and an overall air flow of 100 L. The calculation of the dust release number S_{RD} is based on the following equation.

$$S_{RD} = \frac{m_2 - m_1}{m_0} \cdot 10^5$$

where

- m_0 – known mass of the powder sample
- m_1 – mass of the unused filter
- m_2 – mass of the used filter

The prediction functions of the dust release number S_{RD} are shown in table 2.

Table 2. Prediction functions of the dust release number S_{RD}

Upper limit (dry bulk material)	$S_{RD,UL} = 10^{(3.2357 - 0.69102 \cdot K_{RD})}$
Mean value (dry bulk material)	$S_{RD,MV} = 10^{(3.1083 - 0.66975 \cdot K_{RD})}$
Lower limit (dry bulk material)	$S_{RD,LL} = 10^{(2.918 - 0.62301 \cdot K_{RD})}$
wet bulk material	$S_{RD,wet} = 10^{\left(2.21 \cdot K_{RD} \cdot X_a \cdot \varepsilon^{-1}\right)^{-0.14}} \cdot X_{0.9}$

Rotating drum specific calculation factor:

$$K_{RD} = \frac{\frac{d_{32,GP}}{d_{32}}}{\frac{x_{90,3} - x_{10,3}}{x_{50,3}}} \cdot \frac{1}{\varepsilon},$$

where

- ε – bulk porosity ($0 < \varepsilon < 1$)
- d_{32} – Sauter diameter
- $d_{32,GP}$ – Sauter diameter taking into account all particles larger than **2.9 µm** (for dry bulk material)
- Xa – moisture content of material sample
- $X_{0.9}$ – moisture content of a material at 90% relative humidity

4 UNC Dustiness tester

The UNC Dustiness tester was developed at the University of North Carolina to simulate the dust dispersion by a single blast of compressed air. This batch device has been specifically designed for the testing of potential hazardous or costly powders. Therefore the sample mass is limited to 10 mg per test. The dispersed powder will be collected by two samplers, to quantify the respirable and total dust that was generated with a given energy input. The amount of particles is determined gravimetrically.

The calculation of the dust release number S_{UNC} for respirable (index R) and total dust (index T) is based on the following equations:

$$S_{UNC,T} = 100 \cdot \frac{m_2 - m_1}{m_0} \cdot \frac{6.2}{2.0}$$
$$S_{UNC,R} = 100 \cdot \frac{m_2 - m_1}{m_0} \cdot \frac{6.2}{4.2}$$

where

- m_0 – known mass of the powder sample in g
- m_1 – mass of the unused filter in g
- m_2 – mass of the used filter in g

In case of the forecast functions for the UNC dustiness tester only the amount of total dust is predicted.

Prediction functions of the dust release number:

$$S_{UNC} = 10^{0.93058 \cdot exp(-0.15031 \cdot K_{UNC})}$$

UNC dustiness tester specific calculation factor:

$$K_{UNC} = \frac{\frac{d_{32,GP}}{d_{32}}}{\frac{x_{90,3} - x_{10,3}}{x_{50,3}}} \cdot \frac{1}{\frac{2}{3} \cdot \frac{\varepsilon}{1-\varepsilon} \cdot \frac{d_{32}}{\mu m}}$$

where

- ε – bulk porosity $(0 < \varepsilon < 1)$
- d_{32} – Sauter diameter
- $d_{32,GP}$ – Sauter diameter taking into account all particles larger than **8.8 µm** (for dry bulk material)

5 References

[1] Tim Thorsten Londershausen: Entwicklung von Prognosefunktionen zur Abschätzung der Staubungsneigung von trockenen und feuchten Schüttgütern, Shaker Verlag, Aachen 2018.

[2] Kai Vaupel, Tim Londershausen and Eberhard Schmidt: Process based estimations of dust formation tendency by means of distribution- and material-specific parameters for dry and moist materials, CHoPS 2018.

[3] Vasyl Skorych: Dynamic flowsheet simulation system Dyssol. Introduction to Dyssol. DFG-SPP 1679 “Dyn-Sim-FP” Introductory Workshop, Hamburg, 18.01.2018.