Powder intrinsic properties as dustiness predictor

POWDER INTRINSIC PROPERTIES AS DUSTINESS PREDICTOR

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INTRODUCTION

- Dustiness is the propensity of a powder to emit airborne particles during its handling.
- Stated in new Reach annexes for the characterization of nanomaterials
- Not an intrinsic physical or chemically defined property of a powder
- Value depends on the characteristic properties of the powder and input energy level.
- Two standard tests (Continuous Drop, Rotating drum; CEN EN 15051) provide two different input energy levels (*soon to be replaced by EN 17199 which includes other tests with different input energy levels*)
- Rapidly diversifying nanoscale powders makes it challenging to carry out these tests for all powders.
- Can some of the powder intrinsic physical properties be used to **predict the dustiness**? (exclusion of need of tests)
- If yes, can these properties be further used in producing low emissive powders *i.e.* **safe-by-design powders**?

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OBJECTIVE

Preliminary identification of powder properties capable of predicting the dustiness

theoretical	experimental
Analysis and simulation of simultaneously acting forces on an airborne powder agglomerate	Test of 9 nanoscale powders using continuous drop test configuration

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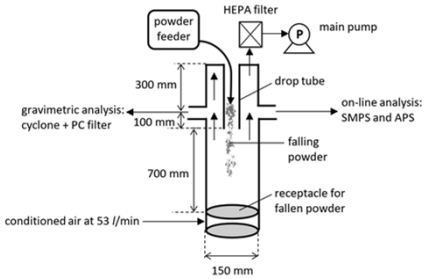
STANDARD CONFIGURATION OF CONTINUOUS DROP (CD) TEST



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THEORETICAL ANALYSIS

- Combined action of three simultaneously acting forces:
  - gravitational force (F_g) on the agglomerate;

$$F_g = \sum_{i=1}^{AAN} \left[\left(\pi \times d_{pi}^3 \times \rho_p\right)/6\right]$$

AAN : Average agglomeration number

$$AAN = [(d_{50} . \rho_{He} . S_{BET} . g)/6]^3$$

  - drag force (F_d) from the upward air flow

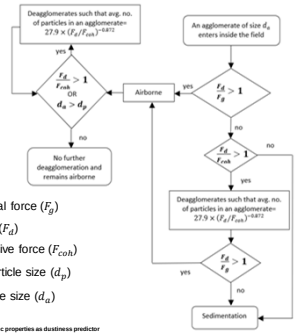
$$F_d = \frac{\pi}{8} C_d \rho_g U^2 d_a^2$$

  - total cohesive force (F_{coh}) inside the agglomerate

$$F_{coh} = \sum_{i=1}^{AAN} \sum_{j=1}^{AAN} \left[\left\{ \frac{A d_{pi} d_{pj}}{12 r_{ij}^2 (d_{pi} + d_{pj})} \right\} + \left\{ (\Delta p_{ij})\, \pi r_{ij}^2 + \gamma_{ij} (2\pi r_{ij}) \cos \alpha_{ij} \right\} + \left| k \frac{q_i . q_j}{r_{ij}^2} \right| \right]$$

van der Waals force | Capillary force | Electrostatic force

AEROSOLIZATION CRITERION

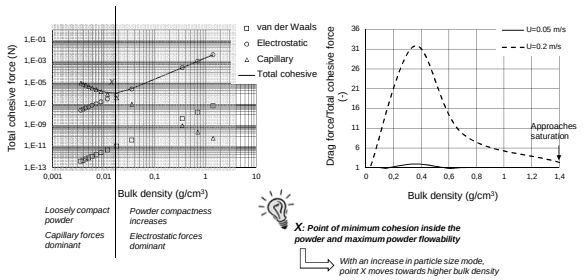


gravitational force (F_g)
drag force (F_d)
total cohesive force (F_{coh})
primary particle size (d_p)
agglomerate size (d_a)

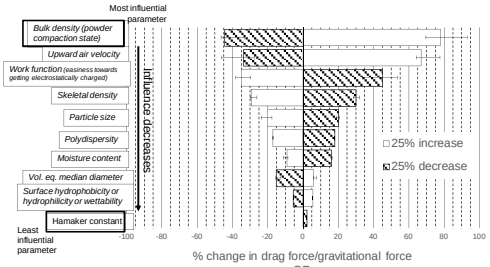
Assumptions:

1. Once dispersed, the powder particles do not reagglomerate when collided.
2. Radius of the water meniscus cross-section between two powder particles can be approximated as the distance between them.
3. The medium around an agglomerate/particle while falling down is air at atmospheric pressure and room temperature.

EXAMPLE RESULTS ON BULK DENSITY FROM THEORETICAL ANALYSIS



SENSITIVITY ANALYSIS OF THEORETICAL ANALYSIS



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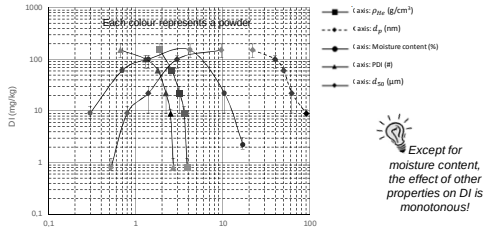
EXPERIMENTAL RESULTS (1/3)

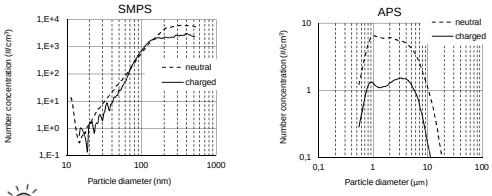
Effect of powder skeletal density (ρ_{He}), primary particle size (d_p), *moisture content*, dispersity (*PDI*) and volume equivalent median particle diameter (d_{50})



Except for moisture content, the effect of other properties on DI is monotonous!

EXPERIMENTAL RESULTS (2/3)

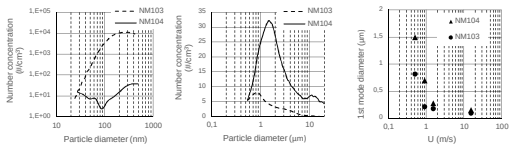
Effect of powder charging *(charged by manual shaking inside plastic packaging)*

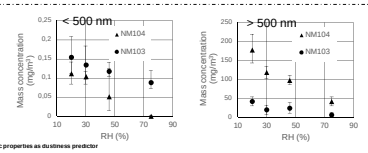


For the same moisture content, powder charging reduces dustiness for particle >200 nm

EXPERIMENTAL RESULTS (3/3)

Effect of powder *wettability*, upward air velocity (*U*) and relative humidity (*RH*)





NM 103: hydrophobic
NM 104: hydrophilic

SOME KEY FINDINGS

- Two most dustiness influencing powder properties:
  - Powder compaction state (bulk density)
  - Powder easiness to get electrostatically charged (state function)
- When powder compaction state is combined with the relative humidity, it signifies powder storage conditions.
- Other 7 powder properties in decreasing order of their influence:
  - skeletal density, particles size, polydispersity, moisture content, median diameter, wettability, Hamaker const.
- Hydrophobic powders tend to generate higher concentrations of nano and sub-micro sized airborne particles than their hydrophilic counterparts.
- The effect of moisture content on reducing the powder dustiness is more pronounced on the hydrophilic powders than the hydrophobic ones.

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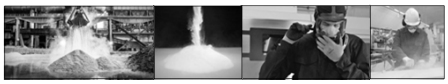
IMPLICATIONS FOR EXPOSURE ESTIMATION AND SAFE INNOVATION

- **Conservative** assumptions & **qualitative** dustiness categorization in various powder exposure estimating models (e.g. STM nano, CB Nanotool, ART etc.)
- Use of the present 9 dustiness influencing powder properties as **industrial hygiene parameters** or **dustiness predictors** in these models for **more effective exposure assessment & management** during powder handling operations
- Some`of these models (GuideNano, NanoSafer etc.) already use the present 9 powder properties as pre-requisites for their reliable functioning.
- Somecof these properties are pre-known from the powder manufacturer.
- OECD WPMN also necessitates the knowledge of these properties for complete hazard profiles of ENMs.
- **Added benefit**: The knowledge of these properties would lead to the safe innovation during the industrial production and processing of powders i.e. **Safe-by-design.**



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THANK YOU FOR YOUR ATTENTION

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