Verband der Mineralfarben-industrie e. V.

Differences between the physical particle size and the aerodynamic diameter of a particle – two sizes, two different worlds

The classification of titanium dioxide powders as potential carcinogen (carc., cat. 2) within the CLP Regulation was published on 18th February 2020.[1] What makes this classification entry in Annex VI special is not only the substantiation based on unspecific particle effects but also its complexity with various conditions and notes. Producers of titanium dioxide containing powders face the challenge of identifying whether or not their products meet these classification criteria. Crucial is the aerodynamic diameter of the particles – a size which has not been used to characterize powders so far.

First measurement results suggest that many titanium dioxide powders do not fulfil the classification criteria. This led to an increasing number of questions as pigments are usually produced with particle sizes below 1 µm and communication of this fact for example in form of d50 values measured in dispersions.

There was a detailed discussion within the VdMi Working Group analytics / dust measurement techniques why a d50 value below 1 µm does by no means contradict a non-classification. The results of this discussion were written down in this information.

Which titanium dioxide powders need to be classified?

Titanium dioxide powders with a share of titanium dioxide containing particles with an aerodynamic diameter ≤ 10 µm of ≥ 1 $\%_m$ fall under the classification. Liquid mixtures are not affected by the classification. However, if such fine particles are included, a warning for the possible formation of dangerous droplets (EUH211) must be added. Solid mixtures must bear the additional note EUH 212, if ≥ 1 $\%_m$ titanium dioxide is included.[2]

Due to the complex nature of the classification entry, a decision cannot be made solely based on the titanium dioxide share. Thus, a thorough analysis for the determination of the aerodynamic diameter is needed which is usually not used to characterize powders in contrast to the particle size.

What do the physical and the aerodynamic diameter describe?

There is no clear definition for the physical diameter of a particle. It describes the physical boundaries – so its outer dimensions / its size – of the particle typically assumed as spherical. It is determined by the differentiation of the particle from its surrounding medium. As an approximation, the diameter typically measured on the dispersed powder is referred to as the particle size and is usually given in the form of d50 values in technical data sheets. Since the particle size has a considerable influence on the properties of pigment powders in the application due to the physical effects of light scattering, this parameter is very precisely monitored and controlled by the manufacturers during production.

> Definition of aerodynamic diameter according to EN 481:
>
> „The diameter of a sphere 1 g cm^{-3} with the same terminal velocity due to gravitational force in calm air, as the particle, under the prevailing conditions of temperature, pressure and relative humidity."

The aerodynamic diameter, on the other hand, describes the sinking behavior of a particle as a dust particle (aerosol) in still air. It is standardized to the shape of a perfect sphere and a density of 1 g/cm³. Therefore, there is no

[1] Delegated Regulation (EU) 2020/217, published in the official journal of the European Union L44 and L51.
[2] See also VdMi FAQs *Consequences of the classification of titanium dioxide powders* (download).

Mainzer Landstraße 55 | www.vdmi.de | Telefon: 069 - 2556 - 1351
60329 Frankfurt | info@vdmi.vci.de | Telefax: 069 - 2556 - 1250

direct correlation to the physical appearance of the particle; the aerodynamic diameter only reflects the sinking behavior of a particle under certain assumptions.

Why do both values differ?

Pigments and fillers mostly have irregular particle shapes. Due to the greater air resistance, they tend to fall more slowly than if they had a perfect spherical shape. In the extreme case, i.e. the presence of leaflets and flakes, there are further, additional effects that slow the case down. The so-called Stokes diameter, i.e. the equivalent diameter of a perfect sphere with the same rate of descent, is therefore smaller than the physical dimensions of the particle.

In addition, pigments and fillers usually have densities that are significantly higher than 1 g/cm³. However, the agglomerates and aggregates present can also have densities of less than 1 g/cm³ due to their porosity. Thus, if the Stokes diameter is normalized to this density, the value then referred to as the aerodynamic diameter is correspondingly larger or smaller.

Due to the high influence of the particle shape on the rate of descent and the formation of agglomerates and aggregates, the aerodynamic diameter cannot simply be calculated from the particle size values. Conversely, no general conclusions can be drawn about the particle size from the aerodynamic diameter of a particle. Therefore, the aerodynamic diameter of a powder is determined by appropriate measurements.

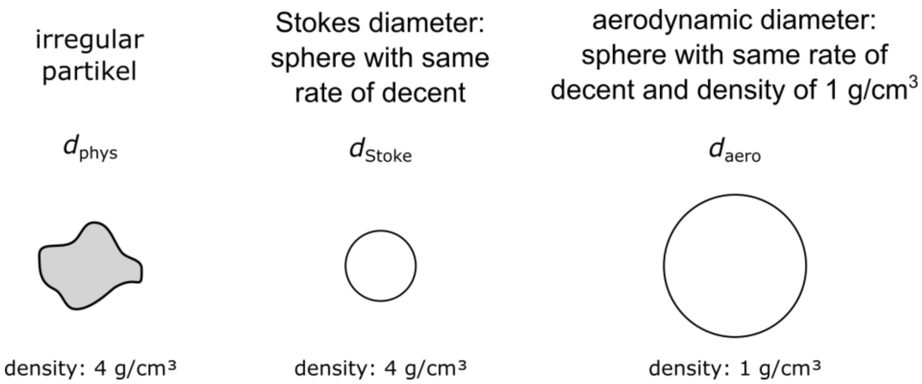

Figure 1: Simplified relationship between the different diameters for describing particles using the example of a primary particle.

How is the aerodynamic diameter of a powder determined?

In order to determine the aerodynamic diameter of a powder, the particles it contains need to be converted into an aerosol first. Various methods of dust generation can be used, which are recorded in the corresponding measurement standards.[3] When determining the aerodynamic diameter, the form of the powder present in the aerosol is decisive. This can be primary particles as well as aggregates and agglomerates. The selected method of aerosol generation as well as external factors such as the air humidity, which can strongly influence the formation of agglomerates, can therefore influence the measurement result.

This is another point why information on the particle size and aerodynamic diameter of a powder can be very different and do not correlate directly with one another. Measurements have shown that pigments and fillers have a strong tendency to form agglomerates and aggregates under normal circumstances. The particles actually present in the aerosol are therefore significantly larger than the (primary) particles, for which particle sizes are determined and given in the form of d50 values.

For the determination of the aerodynamic particle diameter present in the aerosol, different filter systems or analysis methods are defined in the relevant standards.[3]

[3] For example EN 15051, DIN 55992 or EN 17199.

Mainzer Landstraße 55 www.vdmi.de Telefon: 069 - 2556 - 1351
60329 Frankfurt info@vdmi.vci.de Telefax: 069 - 2556 - 1250

Summary – Conclusion

Due to the complex structure of the classification entry for titanium dioxide, it is not possible to make a simple statement about such powder products. The required measurement data for the aerodynamic diameter must be collected separately, as it does not match the average particle size typically specified as the d50 value.

Measurements have shown that pigments and fillers tend to form agglomerates and aggregates, which means that the particles generated during dust formation are significantly larger than the individual particles. Correspondingly, the measured aerodynamic diameter is also in a different order of magnitude.

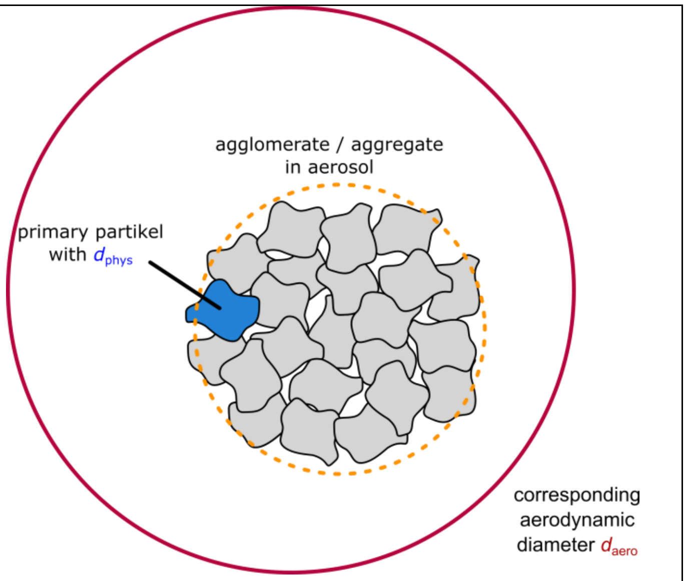

Figure 2: Different meanings of the physical particle size and the aerodynamic diameter.

The specification of a dispersion-based d50 value below the relevant limit of 10 µm for the classification does not contradict a correctly executed, negative classification decision and a corresponding non-labeling of the powder.

Contact:

Verband der Mineralfarbenindustrie e. V.
Dr. Heike Liewald / Dr. Giuliana Beck

liewald@vdmi.vci.de / beck@vdmi.vci.de

The Verband der Mineralfarbenindustrie e. V. represents German manufacturers of inorganic (e.g. titanium dioxide, iron oxides), organic and metallic pigments, fillers (e.g. silica), carbon black, ceramic and glass colours, food colorants, artists' and school paints, masterbatches and products for applied photocatalysis.