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Determination of particle density by sedimentation methods —

Part 1: Isopycnic interpolation approach

Détermination de la densité de particules par méthodes de sédimentation —

Partie 1: Approche par interpolation isopycnique

Reference number
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Foreword

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This document was prepared by Technical Committee ISO/TC 24, *Particle characterization including sieving*, Subcommittee SC 4, *Particle characterization.*

A list of all parts in the ISO 18747 series can be found on the ISO website.

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Introduction

Dispersions are widely used in industry and everyday life. There is a need to understand the density of dispersed particles or droplets, e.g. for physico-chemical calculations like kinematic viscosity of dispersions (ISO 3105), determination of particle size distribution by separation techniques[4][5][7], characterization of core/shell or capsule-like particles, determination of particle compressibility[10] or optimization of dispersion stability by density matching[11].

The density of a body is its mass divided by its volume. This is straightforward for the mass of a larger body or particle. However, experimental determination of the volume of a macroscopic body is difficult. The geometrical volume (length, width and thickness) and the volume relevant for the determination of density can differ due to surface irregularities, fractures, fissures and open and closed pores or the measuring techniques employed.

Density determination of micro-particles, in particular nanoparticles dispersed in a liquid, raises issues, not only for the determination of mass and volume due to the small size but also, and mainly, because of the boundary between the liquid and the particle, which is fuzzy. Molecules in the continuous phase are partially immobilized at the surface. Physico-chemical properties (e.g. viscosity, ion concentration) in the fuzzy coat differ from bulk. This is especially important for small microparticles and nanoparticles which are dispersed in a polymer or biological fluid[12]. The so-called corona can be interpreted as an integral part of the particle and increases the effective/apparent volume compared to the space occupied by the dry material. The thickness of this layer ranges between a few to tens of nanometres and the effective/apparent volume deviates increasingly from the “geometrical” volume, if the particles become smaller. As a consequence, density determination by traditional methods is affected.

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Determination of particle density by sedimentation methods —

Part 1: Isopycnic interpolation approach

1 Scope

This document specifies a method for the determination of the density of solid particles or liquid droplets (below referred to generically as "particles") dispersed in a liquid. The method is based on the fact that a particle wholly immersed in fluid experiences buoyancy equal to the weight of the fluid displaced by this particle (Archimedean principle), and if its mass force matches the buoyant force, it stops gravitational or centrifugal settling/creaming and the particle remains suspended. This implies that the density of the particle equals the density of the liquid. In this document, particle density determination is conducted by analysing the direction of the migration movement of particles dispersed in liquids with densities that are lower and higher than particle density. All particles are of the same material composition.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14887:2000, *Sample preparation — Dispersing procedures for powders in liquids*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
dynamic viscosity
measure of the resistance of a fluid which is being deformed by shear stress

Note 1 to entry: Dynamic viscosity is calculated by shear stress divided by shear rate and determines the dynamics of an incompressible Newtonian fluid.

3.2
migration
directed particle movement (sedimentation or creaming/flotation) due to acting gravitational or centrifugal fields

Note 1 to entry: Sedimentation occurs when density of particles is larger than that of liquid density. Creaming/flotation occurs when density of particles is smaller than that of liquid density. In these two processes, particles move in opposite directions.

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3.3
migration velocity
absolute value of sedimentation or creaming/flotation terminal velocity

Note 1 to entry: Velocity of creaming/flotation is indicated by a negative sign.

3.4
true particle density
ratio of particle mass to particle volume excluding all pores, closed or open, and surface fissures

3.5
skeletal density
ratio of the mass of discrete pieces of solid material to the sum of the volumes of the solid material in the pieces and closed (or blind) pores within the pieces

[SOURCE: ASTM D3766]

3.6
buoyant density
ratio of particle mass to particle volume including filled or closed pores as well as adjacent layers of liquid or other coating materials

4 Symbols

For the purposes of this document, the following symbols apply.

Quantity	Symbol	Unit	Derivative unit
Acceleration	a	m/s^2	
Angular velocity	ω	rad/s	
Dynamic viscosity	η	Pa·s	mPa·s
Force due to buoyancy	F_B	N	
Force due to gravity	F_G	N	
Liquid density	ρ_L	kg/m^3	
Particle density	ρ_P	kg/m^3	
Radius	r	m	mm
Rotational frequency	n	s^{-1}	min^{-1}
Standard acceleration due to gravity	g	m/s^2	
Temperature	ϑ	°C	
Time	t	s	
Velocity	v	m/s	
Velocity measurand	y		
Volume	V	m^3	
Wavelength	λ	m	nm

5 Basic principle of method

The Archimedean principle states that a particle wholly immersed in liquid experiences buoyancy equal to the weight of the fluid displaced by this particle. The balance of the weight forces of a particle due to gravity, F_G, and of buoyancy force, F_B, determines whether its net gravitational motion is upward, downward, or neither [Formula (1)].

$$F_G = \rho_P \cdot V \cdot g = F_B = \rho_L \cdot V \cdot g \quad (1)$$

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