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Particle size analysis — Image analysis methods —

Part 2: Dynamic image analysis methods

Analyse granulométrique — Méthodes par analyse d'images —
Partie 2: Méthodes par analyse d'images dynamiques

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 13322-2:2006), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the text has been aligned with changes introduced in ISO 13322-1:2014;

— clauses on instrumentation (principle) and operational procedures have been significantly expanded;

— a new clause on accuracy and instrument qualification using particulate reference materials has been added.

A list of all parts in the ISO 13322 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

The ISO 13322 series is applicable to the analysis of images for the purpose of determining particle size distributions. The purpose of this document is to provide guidance for measuring and describing particle size distribution, using image analysis methods where particles are in motion. This entails using techniques for dispersing particles in liquid or gas, taking in-focus, still images of them while the particles are moving and subsequently analysing the images. This methodology is called dynamic image analysis.

There are several image capture methods. Some typical methods are described in this document.

ISO 13322-1 on static image analysis methods assumes that an adequate image has already been captured and concentrates upon the analysis of these images.

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Particle size analysis — Image analysis methods —

Part 2: Dynamic image analysis methods

1 Scope

This document describes a method to transfer the images from particles having relative motion to binary images within practical systems, in which the particles in the images are individually separated. Images of moving particles are created by an optical image capture device. Effects of particle movement on the images are either minimized by the instrumentation or corrected by software procedures. This method is applicable to the particle images that are clearly distinguishable from static background. Further processing of the binary image, which is then considered as static, is described in ISO 13322-1. A dynamic image analysis system is capable of measuring a higher number of particles compared to static image analysis systems. This document provides guidance on instrument qualification for particle size distribution measurements by using particulate reference materials. This document addresses the relative movement of the particles with respect to each other, the effect of particle movement on the image (motion blur), the movement and position along the optical axis (depth of field), and the orientation of the particles with respect to the camera.

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 9276-1, *Representation of results of particle size analysis — Part 1: Graphical representation*

ISO 9276-2, *Representation of results of particle size analysis — Part 2: Calculation of average particle sizes/diameters and moments from particle size distributions*

ISO 9276-6, *Representation of results of particle size analysis — Part 6: Descriptive and quantitative representation of particle shape and morphology*

ISO 13322-1, *Particle size analysis — Image analysis methods — Part 1: Static image analysis methods*

ISO 14488, *Particulate materials — Sampling and sample splitting for the determination of particulate properties*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13322-1 and the following apply.

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

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

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

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3.1.1
acceptable depth of field
<dynamic image analysis> depth with respect to the focal depth where the sharpness of the edges of the particle images is accepted for segmentation

Note 1 to entry: The acceptable depth of field is decided by the software based on the sharpness of the images and is also dependent on the particle size.

3.1.2
accuracy
closeness of agreement between a test result or measurement result and the *true value* (3.1.20)

Note 1 to entry: In practice, the accepted reference value is substituted for the true value.

Note 2 to entry: The term “accuracy”, when applied to a set of test or measurement results, involves a combination of random components and a common systematic error or bias component.

Note 3 to entry: Accuracy refers to a combination of *trueness* (3.1.19) and *precision* (3.1.12).

[SOURCE: ISO 3534-2:2006, 3.3.1]

3.1.3
certified reference material
CRM
reference material (3.1.13) characterised by a metrologically valid procedure for one or more specified properties, accompanied by an RM certificate that provides the value of the specified property, its associated uncertainty, and a statement of metrological traceability

Note 1 to entry: The concept of value includes a nominal property or a qualitative attribute such as identity or sequence. Uncertainties for such attributes may be expressed as probabilities or levels of confidence.

Note 2 to entry: Metrologically valid procedures for the production and certification of RMs are given in, among others, ISO 17034 and ISO Guide 35.

Note 3 to entry: ISO Guide 31 gives guidance on the contents of RM certificates.

Note 4 to entry: ISO/IEC Guide 99:2007 has an analogous definition.

[SOURCE: ISO Guide 35:2017, 3.2]

3.1.4
flow cell
measurement cell inside which the gas- or liquid-particle mixture flows

3.1.5
frame coverage
<dynamic image analysis> fraction of the image area that is obscured by the projection area of all segmented particles counted in the image

Note 1 to entry: Frame coverage can be expressed as a part or percentage of the image area.

3.1.6
intermediate precision
<dynamic image analysis> *accuracy* (3.1.2) and precision under *intermediate precision conditions* (3.1.7)

[SOURCE: ISO 3534-2:2006, 3.3.15, modified — "and precision" and the field of application "dynamic image analysis" have been added.]

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3.1.7
intermediate precision conditions
<dynamic image analysis> conditions where test results or measurement results are obtained on different dynamic image analysis instruments and with different operators using the same prescribed method

Note 1 to entry: There are four elements to the operating condition: time, calibration, operator and equipment.

3.1.8
image capture device
matrix camera or line scan camera for converting an optical image to digital image data

3.1.9
measurement zone
volume in which particles are measured by an image analyser, formed by the measurement frame including a third dimension from the *acceptable depth of field* (3.1.1)

Note 1 to entry: The measurement zone is defined by the software (see 3.1.1).

3.1.10
orifice tube
tube with an aperture through which a stream of fluid with dispersed particles flows

3.1.11
illumination
continuous illumination for an *image capture device* (3.1.8) with an electronic exposure time controller, or illumination of short duration for a synchronized image capture device

3.1.12
precision
closeness of agreement between independent test/measurement results obtained under stipulated conditions

Note 1 to entry: Precision depends only on the distribution of random errors and does not relate to the *true value* (3.1.20) or the specified value.

Note 2 to entry: The measure of precision is usually expressed in terms of imprecision and computed as a standard deviation of the test results or measurement results. Less precision is reflected by a larger standard deviation.

Note 3 to entry: Quantitative measures of precision depend critically on the stipulated conditions. *Repeatability conditions* (3.1.15) and reproducibility conditions are particular sets of extreme stipulated conditions.

[SOURCE: ISO 3534-2:2006, 3.3.4]

3.1.13
reference material
RM
material, sufficiently homogeneous and stable with respect to one or more specified properties, which has been established to be fit for its intended use in a measurement process

Note 1 to entry: RM is a generic term.

Note 2 to entry: Properties can be quantitative or qualitative, e.g. identity of substances or species.

Note 3 to entry: Uses may include the calibration of a measurement system, assessment of a measurement procedure, assigning values to other materials, and quality control.

Note 4 to entry: ISO/IEC Guide 99:2007 has an analogous definition, but restricts the term “measurement” to apply to quantitative values. However, ISO/IEC Guide 99:2007, 5.13, Note 3 (VIM), specifically includes qualitative properties, called “nominal properties”.

[SOURCE: ISO Guide 35:2017, 3.1]

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3.1.14
repeatability
precision (3.1.12) under *repeatability conditions* (3.1.15)

Note 1 to entry: Repeatability can be expressed quantitatively in terms of the dispersion characteristics of the results.

[SOURCE: ISO 3534-2:2006, 3.3.5]

3.1.15
repeatability conditions
observation conditions where independent test/measurement results are obtained with the same method on identical test/measurement items in the same test or measuring facility by the same operator using the same equipment within short intervals of time

Note 1 to entry: Repeatability conditions include:

— the same measurement procedure or test procedure;

— the same operator;

— the same measuring or test equipment used under the same conditions;

— the same location;

— repetition over a short period of time.

[SOURCE: ISO 3534-2:2006, 3.3.6]

3.1.16
sampling volume
volume in which the particles are within the field of view of the image analyser including a third dimension from the *sampling volume depth* (3.1.17)

3.1.17
sampling volume depth
length which describes the extent of the particle field in front of the camera

3.1.18
sheath flow
particle-free fluid flow surrounding particle-laden fluid for directing particles into a specific *measurement zone* (3.1.9)

3.1.19
trueness
closeness of agreement between the expectation of a test result or a measurement result and a *true value* (3.1.20)

Note 1 to entry: The measure of trueness is usually expressed in terms of bias.

Note 2 to entry: Trueness is sometimes referred to as “accuracy of the mean”. This usage is not recommended.

Note 3 to entry: In practice, the accepted reference value is substituted for the true value.

[SOURCE: ISO 3534-2:2006, 3.3.3]

3.1.20
true value
value which characterizes a quantity or quantitative characteristic perfectly defined in the conditions which exist when that quantity or quantitative characteristic is considered

Note 1 to entry: The true value of a quantity or quantitative characteristic is a theoretical concept and, in general, cannot be known exactly.

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Note 2 to entry: For an explanation of the term “quantity”, refer to ISO 3534-2:2006, Note 1 of 3.2.1.

[SOURCE: ISO 3534-2:2006, 3.2.5]

3.2 Symbols

In this document the symbol *x* is used to denote the particle sizes. However, it is recognized that the symbols *d* and *D* are also widely used to designate these values (see ISO 9276-2).

a	moving distance of a particle during time t
A_i	projected area of particle i after segmentation
A_{real}	projected area of the static spherical particle whose shape has been approximated by an ellipsoid
A_{meas}	projected area of the measured particle whose shape has been approximated by an ellipsoid
b	measured size of binary particle image, including effects from motion blur
k	coverage factor
q^*	distribution density
$q_0{}^*$	distribution density by number
$q_3{}^*$	distribution density by volume
Q_r	cumulative undersize distribution of quantity r
$Q_r(x)$	cumulative distribution at selected particle sizes x
r	quantity type; number ($r=0$), area ($r=2$) or volume ($r=3$)
σ_s	standard deviation of the test samples
σ	standard deviation
t	effective exposure time
T	threshold level
u_m	measurement uncertainty
u_{CRM}	uncertainty of an assigned value of a certified reference material
u_{RM}	uncertainty of a characterized value of a reference material
U_{lim}	total value of the uncertainty used as the final acceptance/rejection limits for qualification tests
v	particle velocity
x	particle size
$x_{10,r}$	particle size corresponding to 10 % of the cumulative undersize distribution
$x_{50,r}$	particle size corresponding to 50 % of the cumulative undersize distribution
$x_{90,r}$	particle size corresponding to 90 % of the cumulative undersize distribution
x_A	area equivalent diameter

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