
**Measurement and characterization of
particles by acoustic methods —**

**Part 2:
Guidelines for linear theory**

*Caractérisation des particules par des méthodes acoustiques —
Partie 2: Théorie linéaire*



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Published in Switzerland

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Foreword

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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. www.iso.org/directives

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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 WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 24, *Particle characterization including sieving*, Subcommittee SC 4, *Particle characterization*.

ISO 20998 consists of the following parts, under the general title *Measurement and characterization of particles by acoustic methods*:

- *Part 1: Concepts and procedures in ultrasonic attenuation spectroscopy*
- *Part 2: Guidelines for linear theory*

Introduction

It is well known that ultrasonic spectroscopy can be used to measure particle size distribution (PSD) in colloids, dispersions, and emulsions (References [1][2][3][4]). The basic concept is to measure the frequency-dependent attenuation or velocity of the ultrasound as it passes through the sample. The attenuation spectrum is affected by scattering or absorption of ultrasound by particles in the sample, and it is a function of the size distribution and concentration of particles (References [5][6][7]). Once this relationship is established by empirical observation or by theoretical calculations, one can estimate the PSD from the ultrasonic data. Ultrasonic techniques are useful for dynamic online measurements in concentrated slurries and emulsions.

Traditionally, such measurements have been made off-line in a quality control lab, and constraints imposed by the instrumentation have required the use of diluted samples. By making in-process ultrasonic measurements at full concentration, one does not risk altering the dispersion state of the sample. In addition, dynamic processes (such as flocculation, dispersion, and comminution) can be observed directly in real time (Reference [8]). These data can be used in process control schemes to improve both the manufacturing process and the product performance.

ISO 20998 consists of two parts:

- 20998-1 introduces the terminology, concepts, and procedures for measuring ultrasonic attenuation spectra;
- 20998-2 provides guidelines for determining particle size information from the measured spectra for cases where the spectrum is a linear function of the particle volume fraction.

A further part addressing the determination of particle size for cases where the spectrum is not a linear function of volume fraction is planned.

Measurement and characterization of particles by acoustic methods —

Part 2: Guidelines for linear theory

1 Scope

This part of ISO 20998 describes ultrasonic attenuation spectroscopy methods for determining the size distributions of a particulate phase dispersed in a liquid at dilute concentrations, where the ultrasonic attenuation spectrum is a linear function of the particle volume fraction. In this regime, particle-particle interactions are negligible. Colloids, dilute dispersions, and emulsions are within the scope of this part of ISO 20998. The typical particle size for such analysis ranges from 10 nm to 3 mm, although particles outside this range have also been successfully measured. For solid particles in suspension, size measurements can be made at concentrations typically ranging from 0,1 % volume fraction up to 5 % volume fraction, depending on the density contrast between the solid and liquid phases, the particle size, and the frequency range.

NOTE See References [9][10].

For emulsions, measurements may be made at much higher concentrations. These ultrasonic methods can be used to monitor dynamic changes in the size distribution.

While it is possible to determine the particle size distribution from either the attenuation spectrum or the phase velocity spectrum, the use of attenuation data alone is recommended. The relative variation in phase velocity due to changing particle size is small compared to the mean velocity, so it is often difficult to determine the phase velocity with a high degree of accuracy, particularly at ambient temperature. Likewise, the combined use of attenuation and velocity spectra to determine the particle size is not recommended. The presence of measurement errors (i.e. “noise”) in the magnitude and phase spectra can increase the ill-posed nature of the problem and reduce the stability of the inversion.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14488:2007, *Particulate materials — Sampling and sample splitting for the determination of particulate properties*

ISO 20998-1:2006, *Measurement and characterization of particles by acoustic methods — Part 1: Concepts and procedures in ultrasonic attenuation spectroscopy*

3 Terms and definitions

For the purposes of this document, the terms and definitions in ISO 20998-1 and the following apply.

3.1

coefficient of variation

ratio of the standard deviation to the mean value