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Fine bubble technology — Evaluation method for determining surface tension of ultrafine bubble dispersions

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 281, *Fine bubble technology*.

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.

Introduction

Ultrafine bubble (UFB) dispersion in water has been used to take advantage of UFB's ability to slip into narrow space in various technologies such as desalting from the surface of concrete structure, scrubbing a stain on the floor of restroom, since the early period in the development of UFB technology. Recently some appliances such as showerhead and washing machine have installed a nozzle to generate UFBs. The mechanism of removing substances by UFBs is still under investigation, however, squeezing of bubbles between substrate and substances to be removed is presumed to play an important role. Surface tension is inferred to be one of the basic characteristics pertinent to such behaviour of UFBs.

The standardization of measuring method for surface tension is necessary to evaluate the performance of those products using UFBs. The application of measurement technique of surface tension to UFB dispersion in water requires however, special attention to the fact that the change in surface tension caused by UFBs is rather small compared to that caused by surface active agent. Furthermore, UFB dispersion in water is a mixture of water, UFBs and impurities in water, and hence its surface tension can behave in a different manner compared to that of pure material or homogeneous solution.

This document is intended to specify the evaluation method of surface tension of UFB dispersion in water using three measurement methods, Wilhelmy, du Noüy and the pendant drop method, which have been chosen from those widely used in industries. The standardized evaluation method also enables to measure the surface tension of liquid containing UFB dispersion in dilute surfactant water such as detergent or machining coolant, leading to an easy choice for surfactant matching to UFBs.

Fine bubble technology — Evaluation method for determining surface tension of ultrafine bubble dispersions

1 Scope

This document specifies evaluation methods for surface tension of ultrafine bubble (UFB) dispersion in water.

Three test methods, Wilhelmy, du Noüy and the pendant drop method, are adopted because of their advantages to detect small change in surface tension by UFB dispersion in water and the high accessibility to commercially available instruments.

This document can be used to measure the surface tension of liquid containing UFB dispersion in dilute surfactant water solution such as detergent or machining coolant as well as UFB dispersion in water.

NOTE Measurement data of liquid containing UFB dispersion in dilute surfactant water solution are summarized in Annex D.

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 304:1985, *Surface active agents — Determination of surface tension by drawing up liquid films*

ISO 19403-3:2017, *Paints and varnishes — Wettability — Part 3: Determination of the surface tension of liquids using the pendant drop method*

ISO 20480-1, *Fine bubble technology — General principles for usage and measurement of fine bubbles — Part 1: Terminology*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20480-1 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/

3.1
UFB dispersion
UFBD
liquid which contains ultrafine bubbles

[SOURCE: ISO 21255:2018, 3.2[1]]

4 Apparatus

4.1 General

Measuring instruments which are designed for the following established measuring methods, Wilhelmy, du Noüy and the pendant drop methods, are used with ordinary laboratory apparatus. The instrument for Wilhelmy and du Noüy method and that for the pendant drop method, which are usually commercially available, shall be in accordance with ISO 304:1985, Clause 5 and ISO 19403-3:2017, Clause 5, respectively.

In most cases, the instruments are computerized, and measurement and data analysis software are installed.

Measurement is conducted with measuring unit, a rectangular plate in Wilhelmy, a ring in du Noüy, and a needle in the pendant drop method. The measuring units should be chosen from those recommended by manufacturers of instruments.

A measuring cup for the Wilhelmy and du Noüy methods such as a petri dish and a syringe for the pendant drop method, which hold the sample liquid to be tested, should be made of glass to avoid adsorption of UFBs on the wall thereof.[1],[2]

Special attention should be paid to the cleanliness of apparatus to be in contact with the sample liquid because the change in surface tension by the presence of UFBs is expected to be small in the measurement.

NOTE Specifications for commercially available measurement instruments are provided in Annex A.

4.2 Wilhelmy method

When a plate for measurement is distorted, it should be turned back to normal shape or replaced with a brand-new one.

4.3 du Noüy method

When a ring for measurement is distorted, it should be turned back to normal shape or replaced with a brand-new one.

A special jig to restore the original shape can be provided from the manufacturer of tensiometer.

4.4 Pendant drop method

Outer diameter of needle for the pendant drop method d_0 should be chosen based on the manufacturer's instruction. The relationship between d_0 and σ/ρ the ratio of surface tension σ and sample density ρ illustrated in ISO 19403-3:2017, Clause 5, Figure 2, is an informative guide to find an appropriate needle size.

5 Procedure

5.1 Testing environment

Measurement should be carried out in an air-conditioned room.

The use of a heat regulating unit for a measuring instrument to keep the temperature of sample liquid constant is more desirable.

5.2 Temperature measurement

The temperature of the sample shall be determined immediately before the measurement.

When the measurement is replicated for the same sample liquid, the temperature of the sample should be monitored during the measurement.

Fluctuation of the sample temperature should be kept within 2 °C.

To prevent the contamination during the temperature measurement, attention shall be paid to the cleanliness of the sensor surface of the thermometer.

Temperature should be read with an accuracy of 0,1 °C.

5.3 Handling of the sample

A sample should be kept in an airtight container without air-liquid interface under constant temperature until immediately before testing.[1],[2]

To avoid the increase and decrease in the number of ultrafine bubbles during sampling, the following practical measures are recommended: pouring a sample liquid gently into a measuring cup and syringing a sample liquid slowly.

To keep the homogeneity of the sample liquid, gentle stirring with a motor-driven drum roller illustrated in ISO 20298-1:2018, Annex A,[3] is recommended.

5.4 Cleaning of the measuring unit

5.4.1 Cleaning of the plate and ring

Before every measurement, immersion cleaning with ethanol followed by heating to red heat with the alcohol lamp should be carried out.

A plate and a ring shall be kept in ambient temperature after heating to avoid deformation by quenching with the sample liquid.

5.4.2 Cleaning of the measuring cup and syringe

Immersion cleaning with neutral detergent followed by rinsing well with purified or distilled water should be carried out before measurement.

5.5 Determination

The horizontality of instrument shall be confirmed before determination.

As for the pendant drop method, vibrations and air flow shall be minimized. Special attention should be paid to the reduction in vibration of droplet during measurement when a small size of needle is chosen. Intense exposure to light from outside shall be avoided to keep the precision in optical profilometry of droplet.

Carry out the determination on the sample to be analysed according to the manufacturer's instructions for each instrument.

5.6 Measurement of blank water

To explicitly show the influence of UFBs on surface tension, the surface tension of blank water shall be determined with the methods described in 5.5 and subtract data thereof from those of the sample to be analysed.

NOTE Raw water for fine bubble generation can be used as blank water.

6 Calculation and expression of results

For the practical procedure, it is recommended to use the software supplied by the manufacturers of the instruments.

Alternatively, for Wilhelmy and du Noüy methods, calculation methods are specified in ISO 304:1985, Clause 7.

NOTE 1 The pendant drop method assumes the usage of software for optical profilometry of water drop and calculation of surface tension.

NOTE 2 The feature of the three measurement methods is demonstrated in Annex B.

NOTE 3 The influence of measuring condition on measurement results is demonstrated in Annex C.

7 Test report

The test report shall include the following information.

a) the test method used, together with a reference to this document, i.e. ISO 7392:2024 and information about the measuring instrument used:

— the name of the instrument and its manufacture's name, version of software;

— the specification of the needle used in the pendant drop method;

b) the nature of the water used:

— property of the water sample such as pH, electroconductivity, etc.;

c) the measuring conditions:

— the temperature of the water when the measurement was carried out;

— the retention time of a droplet in the measurement by the pendant drop method;

d) the result in accordance with Clause 6;

e) all circumstances that can have influenced the result.