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Fine bubble technology — Transportation and dispensing systems for agro- and aqua-cultural applications —

Part 1: Ultrafine bubble concentration loss in ultrafine bubble water passing through long-distance plastic pipes

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

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Introduction

Fine bubbles are applied to agro- and aqua-culture in their uses for supplying water, nutrition and chemicals for facilitation of growth, sterilization and cleaning. Ultrafine bubbles are known to exhibit great stability in water, provided that they are used appropriately within their intended application.

However, since their farms are spatially broad and remotely located, water needs to be transported by pipe lines to meet the huge amounts required. Furthermore, in order to see the benefit of applying ultrafine bubbles, the transportation line should maintain consistent fine bubble water characteristics, including its number concentration index of ultrafine bubbles. Many mechanisms can be shown for removal of ultrafine bubbles due to mechanical, chemical and thermodynamical effect to imagine the change in the number concentration index loss due to flow in the pipe. When designing the farming system, a reliable prediction on the removal of ultrafine bubbles in the water on the site is needed.

However, there is no useful test method for data or relevant experiment to evaluate how long ultrafine bubbles can practically survive after long transportation.

This document provides the test method on experimental evaluation on a long transfer plastic pipe system in terms of reduction in the ultrafine bubble concentration index due to the flow in pipes. The system, consisting of a reservoir for ultrafine bubble water and a winding pipe, through which the water is circulated periodically from the reservoir, allows description of concentration loss by empirical equation. Systematic analysis of the data output from the practical test process can benefit users for planning and improving a similar system. An example of deduced formula optimized to reproducing observed data is given in Annex A.

This document cannot be used for any conformity assessment activities on relevant test.

Fine bubble technology — Transportation and dispensing systems for agro- and aqua-cultural applications —

Part 1: Ultrafine bubble concentration loss in ultrafine bubble water passing through long-distance plastic pipes

1 Scope

This document specifies a test procedure, equipment and environment for evaluating the concentration loss of ultrafine bubbles (UFB) due to long-distance transfer of ultrafine bubble water in a plastic pipe. The test results are analysed and expressed in terms of a formula with the flow parameters, pipe length, flow velocity and number of circulations through the pipe. The formula is intended to be used for designing long-distance transport system for industrial applications including agro- and aqua-farming.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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
surviving rate
Φ
ratio of number concentration index of ultrafine bubbles[1] at the entrance of a pipe to that at the end of the pipe

Note 1 to entry: The number concentration index of ultrafine bubbles in the water decreases during the flow through the pump and the winding pipe. The rate is evaluated for a sample taken from a reservoir. The vessel is open to room air and the water level is kept over the inlet and the outlet.

3.2
reservoir
vessel for ultrafine bubble water staying almost at rest during the water circulation filled with the water returning back from pipe at its inlet and fed to the gear pump at its outlet, intended to sample ultrafine bubble water for measurement

3.3
sampling
sampling of ultrafine bubble water from the reservoir using a pipet and sampling bottle for the measurement of a size index and a number concentration index[3]

3.4
long winding pipe
long plastic pipe with small inner diameter winding on the bobbin to simulate the behaviour of the long-distance plastic pipe for practical use

3.5
number of circulation
$\boldsymbol{n}_{\mathbf{p}}$
number of ultrafine bubble water circulation passing through the transport system

Note 1 to entry: The number is defined by the ratio of the product of flow rate in the long winding pipe with elapsed time of an experiment to volume of long winding pipe.

3.6
flow velocity
$\boldsymbol{u}_{\mathbf{d}}$
fluid velocity of ultrafine bubble water in the long winding pipe

3.7
loss factor
$\boldsymbol{k}$
coefficient relating the time derivative of the surviving rate to the surviving rate itself

Note 1 to entry: In the analysis of the report, the relationship is assumed to be linear and the loss factor, k, is its proportional coefficient. See Formula (1).

4 Testing method and data analysis

4.1 Basic testing method

The behaviour of extended long-distance plastic pipe is simulated by a pipe winding by many turns measuring long distance in the testing room. The ultrafine bubble water in a reservoir is pushed in by a pump from one end of the pipe and released back to the reservoir after the water completely passes through the long winding pipe.

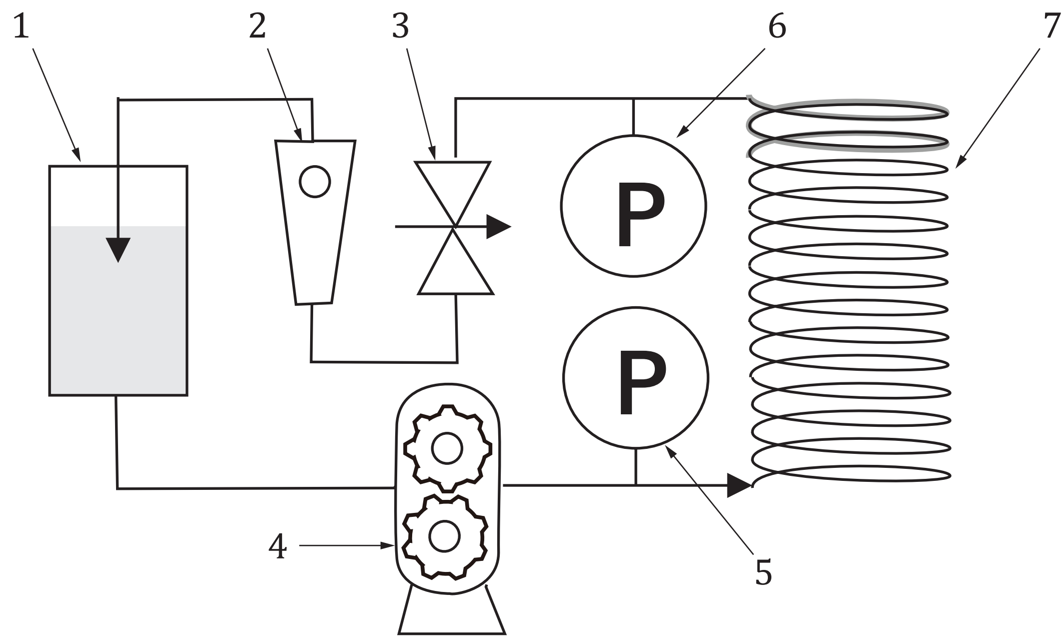
The decrease in number concentration index of ultrafine bubbles after the passing is measured by particle tracking analysis method.

The process is operated continuously by feeding the water from the outlet of the pipe to the inlet through a reservoir and the pressurizing pump. The pushing pressure is kept constant throughout an experiment.

The measurement sample is taken from the reservoir several times synchronous with the period of the circulation. The systematic decrease of number concentration index and elapsed time are recorded for an experiment with selected parameters on inner diameter, d, length of pipe, L, and flow velocity, v_d.

The experiments are conducted for various different values of the parameters and all accumulated output data are analysed for deducing an empirical formula applicable to the condition within the parameter setting.

In Figure 1, a loop indicates one turn of pipe around the bobbin as a part of long winding pipe.



Key

1 reservoir
2 rotor flow meter
3 needle valve
4 gear pump
5 pressure gauge 1
6 pressure gauge 2
7 pipeline

Figure 1 — Schematic diagram of testing system.

4.2 Equipment and environment

The environment for the test operation should be conducted at ambient temperature and air pressure and water should be less exposed to the room air in order not to introduce solid contaminant to the water.

The following equipment should be applied for the test system.

4.2.1 Reservoir

The upper surface is allowing to sample the ultrafine bubble water by pipet. The side wall is transparent or has a window allowing observation of sampling and status of water. An inlet and an outlet are put on the side wall. The outlet has a stop valve and is close to the bottom and the inlet, close to the top. The vertical distance of the openings specifies the volume of the ultrafine bubble water in addition to whole long winding pipe.

The structure of the reservoir is simple enough for simple cleaning and sampling and set stable and in ambient temperature.

4.2.2 Ultrafine bubble water

The ultrafine bubble water, namely sample medium, is generated by an ultrafine bubble generating system, and transferred into the reservoir according to ISO 20298-1 and ISO 21255.

Its volume encompasses the volume of the whole pipe loops plus the volume of the reservoir below outlet mouth plus the dead volume of other apparatus. The homogeneity in the reservoir is confirmed prior to the experiments by using the measurement of number concentration index at a few test points and stirring mechanically.

4.2.3 Pumping

A gear pump is used for pushing the ultrafine bubble water into the pipe with controllable flow velocity and pressure drop. The pump has the capacity depending on the long winding pipe so as to allow the choice of flow velocity in the range 5 m/min to 120 m/min at the pressure drop 5 kPa to 250 kPa.

Both parameters are kept stable during an experiment.

The water pressures at both inlet and outlet of the pipe are measured by Bourdon tube pressure gauge.

Their difference gives the pressure drop. The needle valve gives additional pressure drop monitored by the pressure gauge.

4.2.4 Long winding pipe

The flexible plastic pipe, preferably with visible inside, is wound on the cylindrical column bobbin and fixed to it.

The inner diameter of the pipe allows flexibility for winding and supporting the inner pressure.

4.2.5 Flow meter

The flow rate is measured by the flow meter.

4.2.6 Measuring instrument of number concentration index of ultrafine bubble

The particle tracking analysis method applies. Its operation and principles are defined in ISO 20480-2 and ISO 19430.

4.2.7 Sampling pipet and glass bottle

The pipet and glass bottle with volume capacity more than 10 ml apply. The bottle has elastic rubber packing inner lid and screw lid allowing air tight confinement of ultrafine bubble water at its top.

4.2.8 Thermometer

A thermometer is put in the reservoir and fixed for temperature measurement of ultrafine bubble water.

4.2.9 Stop watch

A stop watch is used to measure elapsed time synchronously to number of circulations.

4.3 Test procedure

Whole testing consists of a few different experiments, with the setup of apparatuses and parameters different from each other.

The following procedure should be applied for each experiment.

a) Prepare enough ultrafine bubble water to supply both the reservoir and the whole long winding pipe.

b) Put ultrafine bubble water to the reservoir and open the valve at the outlet to introduce to the gear pump.

c) Homogenize the ultrafine bubble water in the reservoir by stirring and monitoring the number concentration index and size index distribution of ultrafine bubbles at a few positions in the reserved UFB water.

d) Sample the ultrafine bubble water from the centre of reservoir for measurement of its number concentration index according to planned sequence of an experiment without operating the system.

e) Confirm the number concentration index of ultrafine bubbles is within the measurement range of the instrument for the period of each experiment.

f) Put gear pump on and adjust the flow meter reading to specified value for an experiment.

g) Take the sample at planned sequence of number of circulations, referring to the indication of stop watch.

Bottle the sampled ultrafine bubble water into the glass bottle using the pipet and seal the bottle carefully.

Label the bottle identifying the number of circulations.

h) Repeat step g) on all planned numbers of circulations.

i) Measure the number concentration index and size index of ultrafine bubbles for all planned circulations and record them together with the number and elapsed time at sampling.

j) Check the operation parameters including thermometer reading are not significantly changed and confirm the records up to the number of circulations.

k) Stop the gear pump and repeat the steps.

4.4 Data analysis

Since the mechanism of loss in ultrafine bubbles in a pipe has not been well understood, a simple phenomenological hypothesis is applied to lead the empirical relation with its parameters optimized for reproduction of observed data. The hypothesis applies the following linear decreasing rate formula for the simplest formulation in data analysis as shown in Formula (1).

$$\frac{d\Phi(t)}{dt} = -k\Phi(t) \tag{1}$$

Formula (1) leads to the following explicit and exponential relation as shown in Formula (2):

$$\Phi(t) = \Phi_0 \cdot \exp(-k \cdot t) \tag{2}$$

where, Φ_0 is the initial surviving rate, namely unity. Asymptotically surviving rate Φ(t) approaches zero when t = ∞.

The constant, loss factor, k, depends on the system parameter setting of each experiment which causes the decrease of ultrafine bubbles.

For each experiment, the relationship is applied by numerical fitting to the experimental data. The dependence of the parameter k to setting parameters is studied and confirms the dependence to the flow parameters.

Instead of measuring the number concentration index right before the inlet to the reservoir, the number concentration index in the reservoir is measured. The formula describing the time evolution of the latter number concentration index consists of a UFB number loss term due to the water flow out from the reservoir to the pipe and a UFB number gain term due to the water flow into the reservoir from the pipe. The number concentration index of the latter term is the surviving rate $\Phi(t)$.