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Fine bubble technology — Environmental applications —

Part 2: Test method for evaluating aeration performance of fine bubble jet devices

Technologie des fines bulles — Applications environnementales —

Partie 2: Méthode d'essai pour l'évaluation des performances d'aération des diffuseurs à fines bulles

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Foreword

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

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Introduction

Recent progress in the application of fine bubble technology demonstrates success in various technical fields. Fine bubble jet devices are generally applied in a pure oxygen aeration process to improve the oxygen transfer from gas phase to liquid phase in the environmental engineering fields, such as wastewater treatment and water ecological restoration. Small size jet devices (≤1 m^3/h) are often used for cleaning. Medium size jet devices (1 to 10) m^3/h are often used in aquaculture and agricultural fields. Large size jet devices (≥10 m^3/h) are often used for water treatment and water environment restoration. The fine bubble jet devices are operated in ejector mode (self-aspiration) or injector mode (pressurized oxygen supply). The mode of operation affects the achievable mass transfer and its energy efficiency.

To evaluate aeration device performance there is a need for a standard method for oxygen transfer measurements which can be applied for all types of fine bubble jet devices.

This document is intended to specify the test procedure to be applied to the fine bubble jet devices for oxygen aeration uses. Based on the performance data presented by each bubble generator manufacturer, the engineers who designed the aeration process can calculate how many generators should be used to meet the use requirements.

Fine bubble technology — Environmental applications —

Part 2:
Test method for evaluating aeration performance of fine bubble jet devices

1 Scope

This document describes the test methodology to evaluate the aeration performance of fine bubble jet devices based on an evaluation of the mass transfer coefficient of oxygen from gas to water.

It is applicable to evaluate the performance of fine bubble jet devices for aeration purpose.

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

ISO 20480-2, *Fine bubble technology — General principles for usage and measurement of fine bubbles — Part 2: Categorization of the attributes of fine bubbles*

3 Terms, definitions, symbols and abbreviated terms

For the purposes of this document, the terms and definitions given in ISO 20480-1, ISO 20480-2 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
aeration
oxygenation
process of introducing of air/oxygen into a body of water to increase its oxygen saturation

3.2
pure oxygen
gas containing more than 90 % oxygen

3.3
fine bubble jet device
device that accelerates and releases fluid with fine bubbles, including swirling flow system, ejector system and venture system

3.4
oxygen mass transfer coefficient
$\boldsymbol{K_{L,a}}$
parameter used to assess rates of oxygen transfer from air to water

Note 1 to entry: Expressed in h^{-1} or min^{-1}.

3.5
DO
amount of dissolved oxygen in water or other liquids

Note 1 to entry: Expressed in mg/l.

3.6
standard oxygen transfer efficiency
SOTE
quantity of the introduced oxygen that dissolves in water under standard conditions

Note 1 to entry: The standard conditions are *T*: 293,15 K (20 °C), *P*: 101,325 KPa (mass %).

3.7
standard oxygen transfer rate
SOTR
oxygen mass transfer rate at standard conditions

Note 1 to entry: The standard conditions are *T*: 293,15 K (20 °C), *P*: 101,325 KPa (kg-O_2/h).

3.8
standard aeration efficiency
SAE
mass of oxygen transferred per unit energy at standard conditions

Note 1 to entry: The standard conditions are *T*: 293,15 K (20 °C), *P*: 101,325 KPa (kg-O_2/kW-h).

3.9
cycle frequency
ratio of circulating water flow rate to tank volume

Note 1 to entry: Expressed in h^{-1}.

4 Principle of aeration performance test

Aeration (oxygenation) is an oxygen mass transfer process. Gas liquid mass transfer is highly affected by the generation of gas liquid interface. During the transfer of oxygen from the gas phase to the liquid phase, the resistance mainly comes from the liquid film, the oxygen mass transfer coefficient ($K_{L,a}$) should be given by the following Formula (1). Integrating and sorting Formula (1) gives Formula (2).

$$\frac{dC}{dt} = K_{L,a}\left(C_{\infty}^{*} - C\right) \qquad (1)$$

$$\ln\left(C_{\infty}^{*} - C\right) = \ln\left(C_{\infty}^{*} - C_0\right) - K_{L,a} \cdot t \qquad (2)$$

where

C is the dissolved oxygen concentration in water corresponding to the aeration time t [mg/l];

t is the aeration time [min];

C_0 is the dissolved oxygen concentration value at the test point at time 0 [mg/l];

C_∞^* is the dissolved oxygen concentration value when the test point reaches a steady state [mg/l].

Therefore, $K_{\mathrm{L,a}}$ value can be obtained from an aeration experiment in clean water by taking DO measurements over time.

According to the $K_{\mathrm{L,a}}$ value obtained in the aeration experiment, the $K_{\mathrm{L,as}}$ value at different temperatures should be calculated by Formula (3).

$$K_{\mathrm{L,as}} = K_{\mathrm{L,a}} \times \theta^{20-T} \quad (3)$$

where

$K_{\mathrm{L,as}}$ is the oxygen mass transfer coefficient under standard conditions (T: 293,15 K (20 °C) P: 101,325 KPa) [1/min]:

θ is the temperature correction empirical coefficient, may take 1,024;

T is the water temperature, which is the average temperature during the test [°C].

The standard oxygen mass transfer rate (SOTR, kg/h) should be calculated according to Formulae (4)-(8).

$$O_{\mathrm{TR,S}} = \frac{1}{n}\sum_{i=1}^{n} O_{\mathrm{TR,S},i} \quad (4)$$

$$O_{\mathrm{TR,S},i} = 0{,}06 \times K_{\mathrm{L,as},i} \cdot C_{\infty 20i}^* \cdot V \quad (5)$$

$$C_{\infty 20i}^* = \frac{C_{\infty i}^*}{\tau \cdot \eta} \quad (6)$$

$$\tau = \frac{C_{\mathrm{st}}^*}{C_{\mathrm{s20}}^*} \quad (7)$$

$$\eta = \frac{P_{\mathrm{b}}}{P_{\mathrm{b0}}} \quad (8)$$

where

$O_{\mathrm{TR,S},i}$ is the standard oxygen mass transfer rate (SOTR) at the i th test or test point [kg/h];

$K_{\mathrm{L,as},i}$ is the standard oxygen mass transfer coefficient at the i th test or test point [1/min];

$C_{\infty 20i}^*$ is the saturated dissolved oxygen concentration at the i th test or test point under the standard state (T: 293,15 K (20 °C) P: 101,325 KPa) [mg/l];

V is the volume of water in the oxygen aeration tank [m^3];

$C_{\infty i}^*$ is the steady-state saturated dissolved oxygen concentration at the i th test or test point [mg/l];

τ is the temperature correction factor;

η is the pressure correction factor;

C^*_{st} is the saturated dissolved oxygen concentration value at 101,325 kPa atmospheric pressure and test water temperature [mg/l];

C^*_{s20} is the saturated dissolved oxygen concentration value under the standard state (T: 293,15 K (20 °C) P:101,325 KPa) [mg/l];

P_b is the absolute pressure of the gas during the test [kPa];

P_{b0} is the standard atmospheric pressure, 101,325 kPa.

Standard aeration efficiency (SAE, kgO_2/kWh) should be calculated according to Formula (9):

$$A_{E,S} = \frac{O_{TR,S}}{P} \tag{9}$$

where

$O_{TR,S}$ is the standard oxygen transfer rate [kg/h];

A_{ES} is the standard aeration efficiency (SAE) [kgO_2/kWh]

P is the gross effective power input [kW], and for self-aspiration jet device it includes the pump power; while for a fine bubble jet device applied by a blower, the power consumption [kW] includes the power applied by both water flow and the gas flow.

Standard oxygen transfer efficiency (SOTE) describes how much of the injected oxygen becomes dissolved in water. It is expressed as a percentage with Formula (10). SOTE is determined by the SOTR and the injected flow of oxygen.

$$O_{TE,S} = \frac{O_{TR,S}}{W_{o2}} \cdot 100 \tag{10}$$

where

$O_{TE,S}$ is the standard oxygen transfer efficiency [%];

W_{o2} is the oxygen mass flow [kg/h], which should be calculated by Formulae (11) - (13).

$$W_{O2} = a \cdot q \tag{11}$$

$$a = y \cdot \frac{P_b \cdot M}{8{,}314 \cdot T_b} \tag{12}$$

$$q = \frac{q_b \cdot P_b \cdot T_{b0}}{T_b \cdot P_{b0}} \tag{13}$$