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Noise measurements for UAS (unmanned aircraft systems)

FDIS stage

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This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 16, *Unmanned aircraft systems*.

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

Within the last decade, multirotor unmanned aircraft systems (UAS) have greatly impacted the global market with unique and cost-effective vehicle systems for photography, industrial surveying, logistics, modern agricultural, civil engineering inspection, etc. A UAS can exert a significant impact on the living environments of the human and wildlife during its operation at low altitudes. The adverse environmental impacts include UAS noise. In urban applications, the UAS noise can be more annoying than road traffic or aircraft noise at similar noise levels[1][1].

The characteristics of UAS noise vary in different operating conditions. The modern agricultural UAS are designed to operate at a few meters above ground level. The logistic UAS are operated mainly in cruise conditions. The UAS for civil engineering inspection may operate in both hover and cruise conditions. The flight conditions of UAS are different from large civil transport aircraft and traditional rotorcraft[2][2]. Therefore, the noise characteristics are perceived differently, making the existing noise test codes used for large aircraft, helicopter, and tilt-rotor vehicles unsuitable. These test codes were developed for aircraft that typically operate far above civilians and urban regions, which are remotely related to the multirotor UAS. Currently, there is no internationally agreed procedures for measuring UAS noise in different working conditions.

The recently published European Commission Delegated Regulation EU 2019/945[3][3] for UAS details a noise test code following ISO 3744[4][4]. The EU 2019/945 considers UAS with maximum take-off mass (MTOM) up to 25 kg. The test code measures the sound power level of UAS in indoor and outdoor environments. The regulation was later amended by EU regulation 2020/1058 [5][5] as regards new UAS classes. However, the measurement is limited only to the UAS in hover. In addition, the microphone arrangement is not specified to avoid the influence of unsteady aerodynamic flow induced by the UAS on the acoustic measurement. Also, the directional nature of the noise produced by UAS was not considered. Recently, a guidance on the noise measurement of UAS lighter than 600 kg was published by EASA[6][6].

This document specifies the noise measurement methods for multirotor-powered UAS with an MTOM less than 150 kg. The noise due to the multirotor-powered UAS contains both tonal and broadband content, both of which may have a significant impact on humans. The tonal noise can cause annoyance because humans are sensitive to pitch characteristics[7][7], while the broadband noise can affect the human brainstem auditory evoked response[8][8]. Both the tonal and broadband noise produced by multirotor-powered UAS is dependent on the working conditions, leading to significant differences at different microphone locations.

This document aims at characterizing the UAS noise in different working conditions, but the efforts are left to the manufactures or client requirement to decide the needed measurements. It is not necessary to perform all measurements, and the measurer should select the measurement method according to the purpose. It provides procedures for performing noise measurements at the typical UAS flight-phases including hover, take-off, landing, and cruise. Configurations of the microphones are specified to ensure measurements are made at different locations to quantify the directivity of UAS noise. It also specifies the requirements of how measurements are conducted with the acoustic far-field conditions satisfied. This document focuses on the methods of measuring the sound pressure signals of the UAS under different working conditions, based on which post-processing of the recorded data can be conducted. For example, by computing the narrow-band noise spectra, the tonal noise components can be extracted. However, requirements for signal processing and evaluation of the measured data are not specified in this document. Instead, depending on the test condition, several common noise metrics are recommended, and the procedures to compute these metrics based on the recorded data are given in Annex A~~Annex A~~. This document can promote the understanding of the noise characteristics of UAS and provide reference methods for both manufacturers and regulatory bodies to assess the UAS noise.

Noise measurements for UAS (unmanned aircraft systems)

1 Scope

This document specifies methods for recording the time history of instantaneous sound pressure in several positions around rotor powered unmanned aircraft systems (UAS) with a maximum take-off mass (MTOM) of less than 150 kg in accordance with ISO 21895[9 ~~[9]~~,]. The UAS can be either electrically powered or fuel-powered. It is not applicable to the tilt-rotor or tilt-wing UAS. It does not account for the UAS noise certification or regulation

This document can also be applied to measure the sound pressure from a UAS with either multiple rotors or a single rotor.

This document specifies:

a) ~~a)~~ recommendations and requirements for three different test facilities for the noise measurements of various categories of multirotor-powered UAS:

- ~~—~~ requirements and recommendations of UAS noise tests in anechoic chambers (Clause 7~~(Clause 7);~~);
- ~~—~~ requirements and recommendations of UAS noise tests in anechoic wind tunnels (Clause 8~~(Clause 8).~~).
- ~~—~~ requirements and recommendations of UAS noise tests in outdoor environments (Clause 9~~(Clause 9);~~);

b) ~~b)~~ requirements and recommendations for the configuration of noise measurement for multirotor-powered UAS in hover, vertical take-off and landing, and horizontal cruise;

c) ~~c)~~ recommendations for the test configuration and procedures to minimize the influence of meteorological effects.

2 Normative reference documents

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 26101-1, *Acoustics — Test methods for the qualification of the acoustic environment — Part 1: Qualification of free-field environments*

~~ISO 21895, *Categorization and classification of civil unmanned aircraft systems*~~

ISO/IEC Guide 98~~-~~-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61094~~-~~-4, *Electroacoustics — Measurement microphones – Part 4: Specifications for working standard microphones*

IEC 61260~~-~~-1, *Electroacoustics — Octave-band and fractional-octave-band filters - Part 1: Specifications*

IEC 61672~~-~~-1, *Electroacoustics — Sound level meters – Part 1: Specifications*

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
anechoic chamber
test room in which a free sound field is obtained

[SOURCE: ISO 3745:2012[10][10],, 3.7, modified — ~~the~~The admitted terms have been removed.]

3.2
anechoic wind tunnel
wind tunnel enclosed in an *anechoic chamber* (3.1~~(3.1)~~) for indoor testing

Note 1 to entry: It has sufficiently low *background noise* (3.3~~(3.3)~~) and the reflection of the sound from the test section is minimized.

3.3
background noise
noise from all sources other than the noise source under test

Note 1 to entry: Background noise also includes the airborne noise, structure-borne noise and electrical noise in the instrumentation.

3.4
sound pressure
p
difference between an instantaneous total pressure and the corresponding static pressure

Note 1 to entry: Sound pressure is expressed in pascals (Pa~~)~~).

3.5
A-weighted sound pressure level
$L_{p,A}$
ten times the logarithm to the base 10 of the ratio of the square of A-weighed frequency-band-limited sound pressure p to the square of the reference pressure of p_0=20 µPa

$$L_{p,A} = 10 \log_{10}\left(\frac{p_A^2}{p_0^2}\right)$$

$$L_{p,A} = 10\log_{10}(\frac{p_A^2}{p_0^2})$$

Note 1 to entry: See the definition for "sound pressure level" in ISO/TR 25417[11][11].

Note 2 to entry: The frequency band shall be reported.

3.6
slow time-weighted A-weighted sound pressure level
$L_{p,A,S}$
ten times the logarithm to the base 10 of the ratio of the running time average of the time weighted square of the A-weighted frequency-band-limited sound pressure to the square of the reference pressure of $p_0 = 20\ \mu$Pa$p_0 = 20\mu$Pa

$$L_{p,A,S}(t) = 10\log_{10}\left(\frac{\left(\frac{1}{\tau_S}\right)\int_{t_0}^{t} p_A^2(\xi)e^{-\frac{t-\xi}{\tau_S}}d\xi}{p_0^2}\right)$$

where $\tau_S = 1$s is the exponential time constant for the slow time weighting. t_0 is the starting time and t is the time.

$$L_{p,A,S}(t) = 10\log_{10}(\frac{(\frac{1}{\tau_S})\int_{t_0}^{t} p_A^2(\xi)e^{-\frac{t-\xi}{\tau_S}}d\xi}{p_0^2})$$

where

- τ_S = 1 s is the exponential time constant for the slow time weighting;
- t_0 is the starting time;
- t is the time

[SOURCE: IEC 61672-1: 2013, 3.6, modified — onlyOnly applies to the slow time weighting.]

3.7
maximum slow time-weighted A-weighted sound pressure level
$L_{p,A,Smax}$
$L_{p,A,Smax}$
greatest slow time-weighted A-weighted sound pressure level within a stated time interval

[SOURCE: IEC 61672-1: 2013, 3.7, modified — onlyOnly applies to the slow time weighting.]

3.8
A-weighted sound exposure
$E_{A,T}$
integral of the square of A-weighted frequency-band-limited sound pressure $p_A$$p_A$ over a stated time interval or event of duration T (starting at t_1 and ending at t_2)

$$E_{A,T} = \int_{t_1}^{t_2} p_A^2(t)dt$$

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$$E_{\mathrm{A,T}} = \int_{t_1}^{t_2} p_{\mathrm{A}}^2(t)\mathrm{d}t$$

Note 1 to entry: The frequency band and frequency resolution shall be reported.

Note 2 to entry: See the definition for "sound exposure" in ISO/TR 25417[10][10].].

3.9
A-weighted sound exposure level
$L_{\mathrm{E,A,T}}$
ten times the logarithm to the base 10 of the ratio of the sound exposure, ~~$E_{\mathrm{A,T}}$~~$E_{\mathrm{A,T}}$, to a reference value $E_0 = 4 \times 10^{-10}$ ~~$\mathrm{Pa^2s}$~~ $\mathrm{Pa^2s}$

~~$L_{\mathrm{E,A,T}} = 10\log_{10}\left(\frac{E_{\mathrm{A,T}}}{E_0}\right)$~~

$$L_{\mathrm{E,A,T}} = 10\log_{10}\left(\frac{E_{\mathrm{A,T}}}{E_0}\right)$$

3.10
nominal height
target height of the *unmanned aircraft system (UAS)* (3.16~~(3.16)~~) under test

3.11
hover
operation condition of an *unmanned aircraft system (UAS)* (3.16~~(3.16)~~) that the vertical and horizontal positions and orientation are relatively unchanged

3.12
yaw
operation condition of an *unmanned aircraft system (UAS)* (3.16~~(3.16)~~) that the vertical position is relatively unchanged, while the UAS is rotating with respect to the vertically oriented axis

3.13
take-off
operation condition of an *unmanned aircraft system (UAS)* (3.16~~(3.16)~~) that the height is kept increasing

Note 1 to entry: In this document, it is restricted to vertical motion and the speed is constant except for the initial acceleration process.

3.14
landing
operation condition of an *unmanned aircraft system (UAS)* (3.16~~(3.16)~~) that the height is kept decreasing

Note 1 to entry: In this document, it is restricted to vertical motion and the speed is constant except for the final deacceleration process.

3.15
cruise
operation condition of ~~the~~an *unmanned aircraft system (UAS)* (3.16~~(3.16)~~) that moves unidirectionally at a fixed height

Note 1 to entry: In this document, it means that the speed is constant.

3.16
UAS
unmanned aircraft system
aircraft and its associated elements which are operated remotely or autonomously

Note 1 to entry: In this document, it refers to the vehicles equipped with single or multiple rotors.

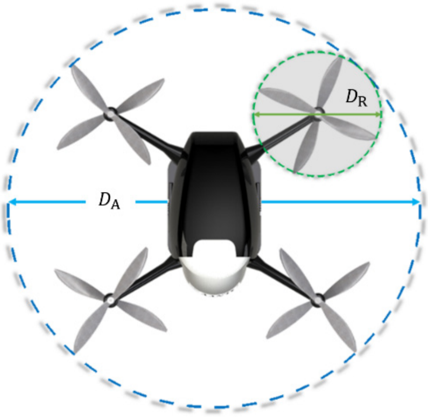
Note 2 to entry: This document is not valid to the tilt-rotor or tilt-wing UAS.

3.17
UAS diameter
D_A
unmanned aircraft system diameter
D_A
diameter of the smallest cylinder that encompasses the projection shape of the *unmanned aircraft system (UAS)* (3.16(3.16)) on a plane

3.18
UAS centre
unmanned aircraft system centre
centre of the cylinder that encompasses the projection of the *unmanned aircraft system (UAS)* (3.16(3.16)) shape on a plane

3.19
propeller diameter
D_R
D_R
diameter of each propeller employed for the multi-propeller powered *unmanned aircraft system (UAS)* (3.16(3.16))

Note 1 to entry: A schematic of D_A and D_R is shown in Figure 1Figure 1..



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