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Civil small and light unmanned aircraft systems (UAS) — Vibration test methods

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Foreword

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

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Introduction

In recent years, the market for lightweight and small civil unmanned aircraft systems (UAS) has developed rapidly. Application areas range from consumer-grade unmanned aircraft vehicles fitted with a camera to industrial-grade unmanned aircraft vehicles used in various safety and inspection operations (e.g. in agriculture, electrical distribution and public safety). As a consequence of being transported from job site to job site, the UAS is exposed to a vibration environment during its lifetime. This document sets out a vibration environment that reflects the situation the UAS experiences during transportation and flight, and to which it can be tested so as to verify whether the test article complies with the applicable performance standards (excluding durability requirements) when subjected to vibration levels specified for the appropriate installation.

Civil small and light unmanned aircraft systems (UAS) — Vibration test methods

1 Scope

This document specifies the test conditions and methods to be used for the vibration testing of unmanned aircraft system (UAS, including unmanned aircraft and ground station) which applies to level II through V according to ISO 21895.

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 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 21384-4, *Unmanned aircraft systems — Part 4: Vocabulary*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041 and ISO 21384-4 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
power spectral density
PSD
degree of variation in energy for each frequency to the acceleration signal in a specific frequency range as a function of frequency

4 Types of vibration test

4.1 Standard vibration test

Standard vibration test is performed to verify whether the UA can work normally when it is subjected to a vibration environment expected during flight, including engine(s) running and rotor(s) turning on ground (e.g. ground resonance prevention). The test may be performed under the conditions involving random test, sinusoidal test, and sine-on-random test.

Measured values should be collected from representative operations and used in testing whenever possible.

4.2 Transportation vibration test

Transportation vibration test is performed to verify whether UAS can work normally after it is subjected to conditions involving vibration induced by transportation.

5 Test conditions

5.1 General

The types of vibration test to which the UA (S) is to be exposed to is dependent on the powerplant type described in Table 1.

Generally speaking, sinusoidal vibration test is applicable to verify whether the design of the product meets the requirements and whether the product is intact after sinusoidal vibration test. Random vibration test mainly simulates the vibration adaptability of products under broadband excitation, especially when the resonance point cannot be determined. Sine-on-random vibration test is mainly used to assess the adaptability of the test article under the condition of superposition of broadband excitation and sinusoidal fixed frequency.

Table 1 — Types of vibration test

UA configuration	Engine/power plant type [a]	Type of vibration test	
Multicopter	Electric motor	Standard vibration	Random; sinusoidal
	/	Transportation vibration	Random test or vehicle field test
Fixed-wing	Electric motor	Standard vibration	Sinusoidal
	Turbine engine, piston engine		Sinusoidal
	Mixed power plant		Envelope value according to the type of mixed power plant
	/	Transportation vibration	Random test or vehicle field test
Unmanned helicopter	Electric motor	Standard vibration	Random; sinusoidal
	Turbine engine, piston engine		Sine-on-random (known frequency)
			Random (unknown frequency)
	Mixed power plant		Envelope value according to the type of mixed power plant
	/	Transportation vibration	Random test or vehicle field test
Ground station (vehicle-mounted/carried)	/	Transportation vibration	Random test or vehicle field test

[a] The engine/power plant types include but are not limited to electric motor, piston engine, turbine engine, mixed power plant, rocket engine, and compressed air power plant according to ISO 21895. In this document, only the commonly used engine/power plant types are considered (e.g. electric motor, piston engine, turbine engine, and mixed power plant).

5.2 Conditions for standard vibration test

5.2.1 Random test

a) Measurements: measured values shall be used wherever possible. If measured values are not available, the values shown in Table 2 shall be used.

b) Axial direction: test shall be performed in each of the test article's three orthogonal axes.

c) Test duration: 1 h for each axis or the time specified by relevant specification of the test article.

5.2.2 Sinusoidal test

a) Measurements: measured values shall be used wherever possible. If measured values are not available, the values shown in Table 2 shall be used.

b) Axial direction: test shall be performed in each of the test article's three orthogonal axes.

c) Test duration: 1 h for each axis or the time specified by relevant specification of the test article.

5.2.3 Sine-on-random test

a) Measurements: measured values shall be used wherever possible. If measured values are not available, the values shown in Table 2 shall be used.

b) Axial direction: test shall be performed in each of the test article's three orthogonal axes.

c) Test duration: 1 h for each axis or the time specified by relevant specification of the test article.

Table 2 — Standard vibration test magnitude

<table>
<tr><th>UA configuration</th><th>Engine/power plant type</th><th colspan="2">Maximum take-off mass
kg</th><th>Type of vibration</th><th>Magnitude</th></tr>
<tr><td rowspan="5">Multicopter</td><td rowspan="5">Electric motor</td><td colspan="2">Level II, III, IV</td><td>Random; sinusoidal</td><td>Refer to Table 3 and Table 4 for details</td></tr>
<tr><td rowspan="2">Level IV</td><td>≤ 10</td><td>Random; sinusoidal</td><td>Refer to Table 3 and Table 4 for details</td></tr>
<tr><td>> 10</td><td>Random; sinusoidal</td><td>Refer to Table 5 and Table 6 for details</td></tr>
<tr><td rowspan="2">Level V</td><td>≤ 50</td><td>Random; sinusoidal</td><td>Refer to Table 5 and Table 6 for details</td></tr>
<tr><td>> 50</td><td>Random; sinusoidal</td><td>Refer to Table 7[a] and Table 8[a] for details</td></tr>
<tr><td rowspan="3">Fixed-wing</td><td>Electric motor</td><td colspan="2">Level II, III, IV, V</td><td>Sinusoidal</td><td>Refer to Table 9[a] for details</td></tr>
<tr><td>Turbine engine, piston engine</td><td colspan="2">Level V</td><td>Sinusoidal</td><td>Refer to Table 10[a] for details</td></tr>
<tr><td>Mixed power plant</td><td colspan="4">Envelope value according to the type of mixed power plant</td></tr>
<tr><td colspan="6">For UA that belongs to both multicopter and fixed-wing, both magnitudes shall be considered based on the engine/power plant type.
The classification of level shall be in accordance with ISO 21895.
[a] For test articles weighing greater than 22,5 kg, a reduction in test levels for frequencies above 60 Hz is allowed using the following schedule:
— test levels may be reduced by 0,10 dB for each 0,5 kg test article weight increment above 22,5 kg to a maximum reduction of 6,0 dB;
— a 6,0 dB reduction would reduce the PSD level to 1/4 of the original level.</td></tr>
</table>

Table 2 *(continued)*

UA configuration	Engine/power plant type	Maximum take-off mass kg	Type of vibration	Magnitude
Unmanned helicopter	Electric motor	Level V	Random; sinusoidal	Refer to Table 7[a] and Table 8 [a] for details
	Turbine engine, piston engine	Level V	Sine-on-random (known frequency)	Refer to Figure 1 and Table 11[a] for details
			Random (unknown frequency)	Refer to Table 12[a] for details
	Mixed power plant	Envelope value according to the type of mixed power plant		

For UA that belongs to both multicopter and fixed-wing, both magnitudes shall be considered based on the engine/power plant type.

The classification of level shall be in accordance with ISO 21895.

[a] For test articles weighing greater than 22,5 kg, a reduction in test levels for frequencies above 60 Hz is allowed using the following schedule:

— test levels may be reduced by 0,10 dB for each 0,5 kg test article weight increment above 22,5 kg to a maximum reduction of 6,0 dB;

— a 6,0 dB reduction would reduce the PSD level to 1/4 of the original level.

Table 3 — Random test levels for multicopter UA (electric motor, level II, III and IV with maximum take-off mass ≤ 10 kg)

Frequency Hz	PSD g^2/Hz
30	0,01
100	0,06
850	0,002
1 000	0,002

Table 4 — Sinusoidal test levels for multicopter UA (electric motor, level II, III and IV with maximum take-off mass ≤ 10 kg)

Frequency Hz	Acceleration g	Logarithmic sweep rate oct/min
30	2,0	1
100	5,0	
850	0,8	
1 000	0,8	

Table 5 — Random test levels for multicopter UA (electric motor, level IV with maximum take-off mass > 10 kg and level V with maximum take-off mass ≤ 50 kg)

Frequency Hz	PSD g^2/Hz
10	0,001
100	0,03
600	0,000 2
1 000	0,000 2

Table 6 — Sinusoidal test levels for multicopter UA (electric motor, level IV with maximum take-off mass > 10 kg and level V with maximum take-off mass ≤ 50 kg)

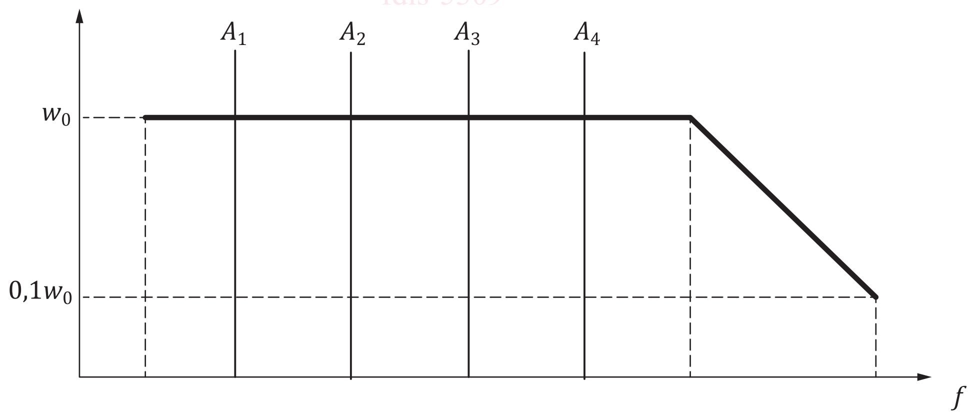
Frequency Hz	Acceleration g	Logarithmic sweep rate oct/min
10	0,4	1
100	3,0	
600	0,2	
1 000	0,2	

Table 7 — Random test levels for multicopter UA (electric motor, level V with maximum take-off mass > 50 kg) and unmanned helicopter (electric motor, level V)

Frequency Hz	PSD g^2/Hz
10	0,012
40	0,012
100	0,002
500	0,002
2 000	0,000 13

Table 8 — Sinusoidal test levels for multicopter UA (electric motor, level V with maximum take-off mass > 50 kg) and unmanned helicopter (electric motor, level V)

Frequency Hz	Double-amplitude mm/g	Logarithmic sweep rate oct/min
15	0,25 mm	1
55	0,25 mm	
500	1,5 g	



Key

f frequency, expressed in Hz

w_0 random PSD curve, expressed in g^2/Hz

A_1 to A_4 sine curves, expressed in g

NOTE The vibration frequencies and are vibration levels are given in Table 9.

Figure 1 — Sine-on-random test curve for multicopter UA (turbine engine, piston engine) and unmanned helicopter (turbine engine, piston engine)

