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

*Aéronefs sans pilote (UAS) civils petits et légers — Méthodes d'essais
de vibrations*

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical 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.

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.

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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)
			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

UA configura- tion	Engine/power plant type	Maximum take-off mass kg	Type of vibration	Magnitude	
Multicopter	Electric motor	Level II, III, IV	Random; sinusoidal	Refer to Table 3 and Table 4 for details	
		Level IV	≤ 10	Random; sinusoidal	Refer to Table 3 and Table 4 for details
			> 10	Random; sinusoidal	Refer to Table 5 and Table 6 for details
		Level V	≤ 50	Random; sinusoidal	Refer to Table 5 and Table 6 for details
			> 50	Random; sinusoidal	Refer to Table 7^a and Table 8^a for details
Fixed-wing	Electric motor	Level II, III, IV, V	Sinusoidal	Refer to Table 9^a for details	
	Turbine engine, piston engine	Level V	Sinusoidal	Refer to Table 10^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 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)

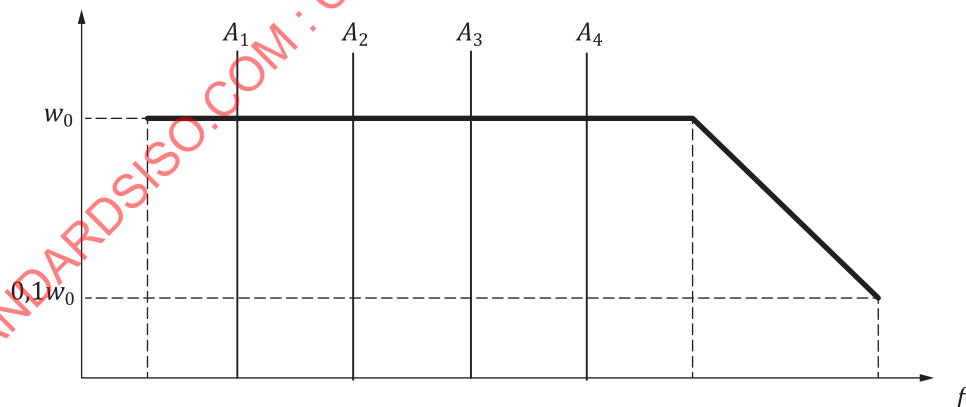
Frequency Hz	Acceleration g	Logarithmic sweep rate oct/min
10	0,4	1
100	3,0	
600	0,2	
1 000	0,2	

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 g²/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)

Table 9 — Sinusoidal test levels for fixed-wing UA (electric motor, Level II, III, IV, 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	

Table 10 — Sinusoidal test levels for fixed-wing UA (turbine engine, piston engine, Level V)

Frequency Hz	Double-amplitude mm/g	Logarithmic sweep rate oct/min
15	0,5 mm	1
55	0,5 mm	
500	3 g	

Table 11 — Sine-on-random test levels (known frequency) for multicopter UA (turbine engine, piston engine) and unmanned helicopter (turbine engine, piston engine)

Sine part		Random part	
Frequency range (f_1 to f_4) Hz	Acceleration (A_1 to A_4) g	Frequency Hz	PSD g^2/Hz
$3 < f_n \leq 40$	$0,04 \times f_n$	10	0,01 (W_0)
$40 < f_n \leq 200$	1,6	300	0,01 (W_0)
		2 000	0,001 ($0,1W_0$)

^a f_1 : first blade passage frequency of the main rotor;
 f_2 : twice first blade passage frequency of the main rotor;
 f_3 : first blade passage frequency of the tail rotor (if the UA is equipped with tail rotor);
 f_4 : twice first blade passage frequency of the tail rotor (if the UA is equipped with tail rotor).

Table 12 — Random test levels (unknown frequency) for multicopter UA (turbine engine, piston engine) and unmanned helicopter (turbine engine, piston engine)

Frequency Hz	PSD g^2/Hz
5	0,005
40	0,05
200	0,05
300	0,01

5.3 Conditions for transportation vibration test

5.3.1 Random test

- a) Measurements: measured values shall be used wherever possible. If measured values are not available, the values shown in [Table 13](#) shall be used.

[Table 13](#) represents the typical power spectrum of road surfaces with good working conditions (e.g. highway). If the expected transportation environment of the product includes off-road and extreme conditions, the test spectrum type shall be selected by referring to other relevant documents.

- b) Axial direction: vertical, transverse and longitudinal axes. When orientation within the vehicle can vary, vibration exposures should be derived from envelopes of possible orientations (e.g. longitudinal and transverse combined, vertical).

NOTE 1 With the test article suspended for test, the longitudinal axis is the axis parallel to the ground plane and passing through the longest dimension of the store. The vertical axis is mutually perpendicular to the ground plane and the longitudinal axis. The transverse axis is mutually perpendicular to longitudinal and vertical axes.

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

NOTE 2 60 min random test per axis is equivalent to 1 600 km road travel for common carrier or truck.

Table 13 — Transportation vibration test conditions

Vertical axis		Transverse axis		Longitudinal axis	
Frequency Hz	PSD g^2/Hz	Frequency Hz	PSD g^2/Hz	Frequency Hz	PSD g^2/Hz
10 ^a	0,015	10 ^a	0,000 13	10 ^a	0,006 5
40	0,015	20	0,000 65	20	0,006 5
500	0,000 15	30	0,000 65	120	0,000 2
		78	0,000 02	121	0,003
		79	0,000 19	200	0,003
		120	0,000 19	240	0,001 5
		500	0,000 01	340	0,000 03
				500	0,000 15

^a The starting frequency can be extended to lowest natural frequency.

5.3.2 Vehicle field test

According to the actual installation or transportation form, the test article is loaded on the vehicle and secured or mounted. The vehicle is then driven over the test surface in a manner that reproduces the transportation or service conditions.

Test surfaces and running distance are determined according to actual conditions. 1 600 km is recommended here when the expected transportation distance is unknown. The test surfaces may include designed test tracks, typical highways, or specific highways between given points (e.g. a specified route between a manufacturing facility and a working place). Potentially, such testing can include all environmental factors (vibration, shock, temperature, humidity, pressure, etc.) related to wheeled vehicle transport.

5.4 Vibration test requirements and recommendations

For the vibration test, the following requirements and recommendations apply.

- Install the test article under test so the input vibratory motion is parallel to one of its three major orthogonal axes. Any test fixture used shall be as rigid and symmetrical as practicable. For standard vibration test, the test article shall be attached to the fixture or vibration table by the means specified in the specification of the test article. For transportation vibration test, the test article shall represent to the actual installation or transportation form (e.g. in a padded case). Test article that is mounted on external vibration/shock isolators shall be tested with the isolators.
- Where applicable, the monitoring accelerometer(s) shall be attached to the test article item undergoing vibration to measure and record the test article's vibration response in the axis of vibration to determine resonant frequencies and amplification factors. Locations selected may include principal structure, printed circuit boards, large components and modules, where practicable.
- The control accelerometer(s) shall be attached to the test fixture as close as practicable to the test article mounting location for each axis of test. When more than one accelerometer is employed for test level control, the average of the accelerometer control signals for sinusoidal test or the average

of the acceleration power spectral densities (PSDs) for random test shall be used as the test level control. For all vibration input types, the appropriate spectrum or acceleration PSD plots shall be made to demonstrate that the control levels meet the test level requirements.

- d) The random vibration signal should have a Gaussian distribution; and the instantaneous vibration acceleration peaks of the control signal may be limited to three times the gradient root mean square (GRMS) acceleration level.
- e) The accuracy of the instrumentation system for measuring sinusoidal acceleration shall be $\pm 10\%$ for acceleration and $\pm 2\%$ for frequency.

5.5 Control level tolerance requirements

5.5.1 Random input control

The acceleration PSD of the test control signal shall not deviate from the specified requirements by more than +3 dB or -1,5 dB below 500 Hz and $\pm 3,0$ dB from 500 Hz to 2 000 Hz. The overall GRMS level of the control signal shall be within +20 % and -5 % of the overall GRMS value for the specified acceleration PSD curve.

5.5.2 Sinusoidal control

The acceleration test level control for any sinusoidal input curve shall be within $\pm 10\%$ of the specified level over the specified frequency range.

6 Test procedure

6.1 Random test

6.1.1 General

The random test shall be performed along each of the three orthogonal axes by following the requirements set out in 6.1.2 to 6.1.5. Only certain functional items (see [Annex A](#)) can be checked during the vibration test; the function/performance inspection before and after test shall be checked according to relevant specifications (e.g. product testing specifications, product development requirements, etc.), which are not included in this document due to the limitations of the laboratory test.

6.1.2 Check before test

- a) Visually inspect the test article to ensure it is free from obvious damages; and inspect the functions of test article according to the relevant specification.
- b) Record the check and inspection results.

6.1.3 Test article installation

- a) Fix the test article directly to the vibration table by means of the fixtures and then install accelerometers.
- b) The control accelerometer(s) shall be attached to the test fixture as close as practicable to the test article mounting location; and the monitoring accelerometer(s) shall be attached to the test article of interest.

6.1.4 Test process

- a) With the test article operating, apply random vibration at the levels determined in [Table 2](#) to the test article for 1 h or the time required by the relevant specification along each axial direction.

Operating means the test article is electronically awake, at least. If possible, it shall be mechanically awake depending on the situation.

- b) During vibration, test the functions of test article according to the relevant specification to verify whether the test article satisfies the requirements of the relevant specification.

6.1.5 Check after test

- a) Visually inspect the test article to ensure it is free from obvious damages; and inspect the functions of test article according to the relevant specification.
- b) Record the check and inspection results.

6.2 Sinusoidal test

6.2.1 General

The sinusoidal test shall be performed along each of the three orthogonal axes by following the requirements set out in [6.2.2](#) to [6.2.5](#). Only certain functional items (see [Annex A](#)) can be checked during the vibration test; the function/performance inspection before and after test shall be checked according to relevant specifications, which are not included in this document due to the limitations of the laboratory test.

6.2.2 Check before test

- a) Visually inspect the test article to ensure it is free from obvious damages; and inspect the functions of test article according to the relevant specification.
- b) Record the check and inspection results.

6.2.3 Test article installation

- a) Fix the test article directly to the vibration table by means of the fixtures and then install accelerometers.
- b) The control accelerometer(s) shall be attached to the test fixture as close as practicable to the test article mounting location; and the monitoring accelerometer(s) shall be attached to the test article of interest.

6.2.4 Test process

- a) With the test article operating, perform sine frequency sweep cycles varying the vibration frequency over the appropriate frequency range from lowest to the highest (up-sweep) to the lowest (down-sweep) specified frequencies with a logarithmic sweep rate not exceeding 1 oct/min.
- b) During the initial up-sweeps, record plots of the accelerometers at the response locations selected and identify the critical frequencies. Critical frequencies are defined as those frequencies where:
 - 1) mechanical vibration resonances have peak acceleration amplitudes greater than twice the input acceleration amplitude; or

- 2) a change in performance or behaviour is noticeable whether or not performance standards are exceeded.
- c) Keeping the test article in working state, perform sine vibration sweep cycle along each axis for 1 h or the time required by the relevant specification.
- d) Record any critical change of frequency during the test.
- e) During vibration, test the functions of test article according to the relevant specification to verify whether the test article satisfies the requirements of the relevant specification.

6.2.5 Check after test

- a) Visually inspect the test article to ensure it is free from obvious damages; and inspect the functions of test article according to the relevant specification.
- b) Record the check and inspection results.

6.3 Sine-on-random test

6.3.1 General

The applied controlled input vibration level shall have a frequency content of the sum of the sinusoidal frequencies and the wide-band random test levels determined above. The sinusoidal frequencies shall be varied at a logarithmic sweep rate not exceeding 1 oct/min from $0,9 \times f_n$ to $1,1 \times f_n$ (where f_n are the sinusoidal frequencies of the test spectrum).

The sine-on-random test shall be performed along each of the three orthogonal axes by following the requirements set out in 6.3.2 to 6.3.5. Only certain functional items (see [Annex A](#)) can be checked during the vibration test; the function/performance inspection before and after test shall be checked according to relevant specifications, which are not included in this document due to the limitations of the laboratory test.

6.3.2 Check before test

- a) Visually inspect the test article to ensure it is free from obvious damages; and inspect the functions of test article according to the relevant specification.
- b) Record the check and inspection results.

6.3.3 Test article installation

- a) Fix the test article directly to the vibration table by means of the fixtures and then install accelerometers.
- b) The control accelerometer(s) shall be attached to the test fixture as close as practicable to the test article mounting location; and the monitoring accelerometer(s) shall be attached to the test article of interest.

6.3.4 Test process

- a) With the test article operating, apply sine-on-random vibration at the levels determined in [Table 2](#) to the test article for 1 h or the time required by the relevant specification along each axial direction.
- b) During vibration, test the functions of test article according to the relevant specification to verify whether the test article satisfy the requirements of the relevant specification.