INTERNATIONAL STANDARD

ISO 5312

First edition
2023-10

Civil small and light unmanned aircraft (UA) — Sharp injury to human body by rotor blades — Evaluation and test method

Aéronefs sans pilote (UA) civils petits et légers — Coupure sur le corps humain par des pales de rotor — Évaluation et méthode d'essai

Reference number
ISO 5312:2023(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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.

Introduction

The global civil unmanned aircraft (UA) industry is developing rapidly and its application market is vast. In particular, the amount of low-altitude, slow-speed, small and light UA increases significantly, becoming the majority of civil UA. At present, the civil small and light UA include multicopter UA, fixed-wing UA and helicopter UA. The multicopter UA are widely used due to the simplicity, highly intelligent flight control system, and high stability. Considering uncontrollable factors, such as the reliability of UA and operational issues, collisions are inevitable in some circumstances. The safety of people in public place is critical.

Blunt and sharp injuries are caused by the collision between a UA and human body. The blunt injury is caused by the impact of a UA at a speed, while the sharp injury refers to the laceration and puncture to human body caused by high-speed rotating blades of a UA. Due to the lightweight and high-manoeuvrability of the small and light UA, the sharp injury caused by the high-speed rotating blades can be more serious as a safety threat to human body comparing to the blunt injury.

Previous tests have shown that the sharp injury caused by the rotor blades of small and light UA is related to the rotational speed, blades size, blade material and impact speed. However, there is still no standard or guidance available to specify the key techniques, such as the selection of impact environment and equipment, the test method coupling the rotational speed of blades and flight speed of UA, the evaluation criteria for tests. Without an appropriate method to evaluate and verify the safety of UA rotor blades, it is not conducive to the safety management and safety assessment of small and light UA market. Therefore, it is of great significance to establish a standard to specify the test and evaluation methods for sharp injury to human body caused by UA rotor blades.

This document specifies requirements for the safety test method for the laceration and puncture caused by the civil small and light UA, including test principles, test methods, test equipment, test specimens, test items, test procedures, result evaluation, etc. In addition, the establishment of the standard supports the evaluation of the laceration and puncture caused by the civil small and light UA. The implementation of this document promotes the development of the test technology on the laceration and puncture caused by the civil small and light UA, thereby improving the safety of the product.

Currently, the test method of laceration and puncture caused by the civil small and light UA has not been standardized. The published International Standards for UA, such as ISO 21384-4, have not provided the expected guidance for the safety test of the laceration and puncture caused by multicopter UA at this stage.

The main technical contents of this document are the following:

a) the test principles and method of the laceration and puncture caused by the rotor blades of civil small and light multicopter UA;

b) the test equipment of the laceration and puncture caused by the rotor blades of civil small and light multicopter UA;

c) the test items and procedures of the laceration and puncture caused by the rotor blades of civil small and light multicopter UA;

d) the result evaluation method of the laceration and puncture caused by the rotor blades of civil small and light multicopter UA.

Civil small and light unmanned aircraft (UA) — Sharp injury to human body by rotor blades — Evaluation and test method

1 Scope

This document specifies the evaluation and test method for sharp injury to human body caused by rotor blades of civil small and light unmanned aircraft (UA), including injury scale, requirements, content, tests, results, etc.

This document is applicable to evaluating and testing the sharp injury to human body caused by rotor blades of civil small and light UA (with maximum take-off mass between 0,25 kg to 4 kg, which are between the levels II and III as categorized by ISO 21895), including multicopter UA, unmanned helicopters and other rotor UA.

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 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 21384-4, ISO 21895 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
sharp injury
injury or dysfunction to skin tissue caused by *laceration* (3.5) or puncture by UA rotor blades

3.2
sharp injury scale
severity of skin injury or dysfunction to skin tissue caused *laceration* (3.5) or puncture by UA rotor blades

3.3
accumulating loading impact test
test that a UA is driven by an accumulator loading device to impact the target

3.4
bionic skin
substitution with similar physical properties to human skin to be used in *sharp injury* (3.1) tests

3.5
laceration
type of damage to skin tissue caused by the circumferential motion of the UA blade tip due to rotation

3.6
puncture
type of deep and subcutaneous damage to skin tissue caused by the end of the UA blade due to radial movement of the blade

4 Sharp injury scale

The sharp injury to human body caused by UA rotor blades are divided into three scales, as shown in Table 1.

Table 1 — Scale of sharp injury to human body

Injury scale	Scale 1	Scale 2	Scale 3
Injury description	Only scratches or bruises on skin [a]	Minor injuries that can be handled by themselves [b]	Injuries that require medical intervention [c]
[a] Non-sharp injury.			
[b] Injuries can be processed with a basic first-aid treatment.			
[c] Injuries requiring an emergency medical attention.			

5 Requirements for sharp damage

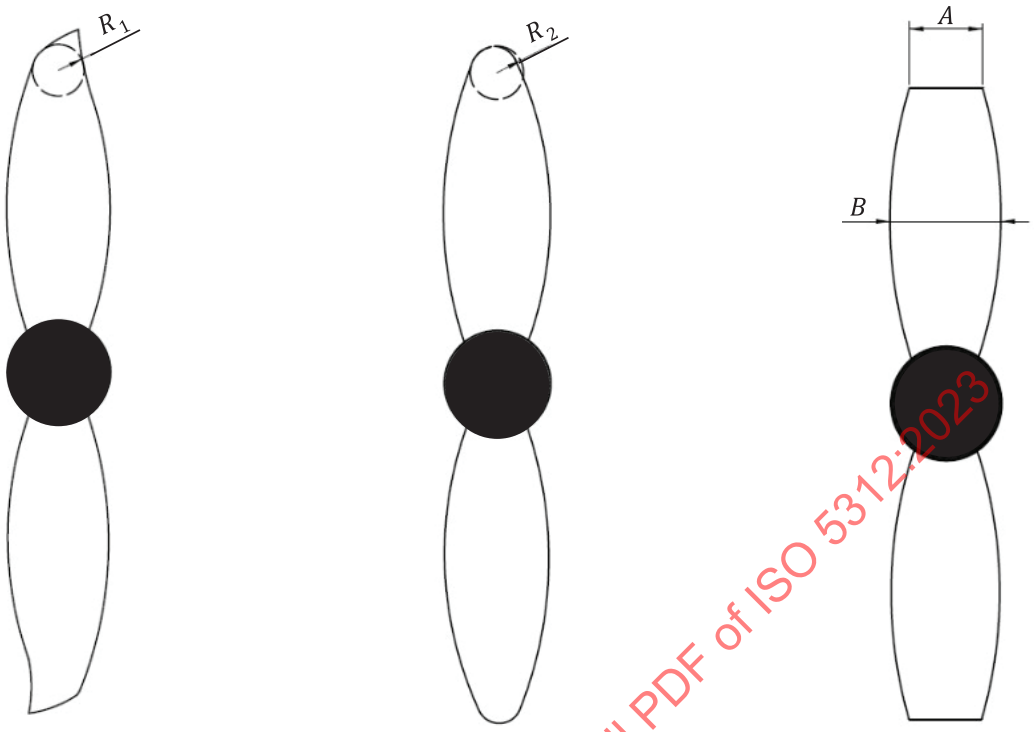
The requirements for sharp damage to the human body by the rotor blades of civil small and light UA are divided into analysis levels and test levels; and it is sufficient to meet either. The details of analytical levels are shown in Table 2; and the details of test levels are shown in Table 3. When the analysis method is used, the blade material should not be metal, and the geometry of the blade shall meet any of the following requirements:

a) an asymmetrical propeller tip shall not have a leading-edge radius R_1 of less than 1 mm [Figure 1, a)];

b) a rounded propeller tip shall not have a radius R_2 of less than 1 mm [Figure 1, b)];

c) a square propeller tip shall have a tip chord A of more than 2 mm or ctip > 30 % of the maximum blade chord B whichever is larger [Figure 1, c)];

d) foldable propellers of any tip shape other than having protrusions in the direction of rotation shall fold back in the event of a contact.



a) Asymmetrical propeller tip b) Rounded propeller tip c) Square propeller tip

Figure 1 — Blade geometry

As shown in Tables 2 and 3, it is acceptable when the injury is on the scale 1 or scale 2. It is unacceptable when the injury is on the scale 3.

Table 2 — Analysis level

Injury scale	Scale 1	Scale 2	Scale 3
Acceptability	Acceptable injury	Acceptable injury	Unacceptable injury
Plastic blade	$\frac{N}{15\,000}+\frac{K}{2\,400}\le 1$	$\frac{N}{44\,000}+\frac{K}{7\,200}\le 1$	> Scale 2
other blade		$\frac{N}{22\,000}+\frac{K}{3\,600}\le 1$	> Scale 2

Key

N: the speed of blades under the maximum thrust (r/min)

$K = 6\cdot 10^{-7}\left(m r^2 N^2\right)$, where m is the mass of the rotor blade(kg), and r is the radius of rotor blades (mm).

Table 3 — Test level

Injury scale	Scale 1	Scale 2	Scale 3
If it acceptable	Acceptable injury	Acceptable injury	Unacceptable injury
Test results	No visible injury	Wound length ≤ 20 cm; Not deep into subcutaneous tissue	> Scale 2

6 Evaluation requirement

6.1 Test purpose

Test and evaluate the severity of the sharp injury to human body caused by UA rotor blades.

6.2 Test conditions

6.2.1 Technical documents

The documents for the evaluation shall include:

a) design documents, drawings and interface documents that related to the tests;

b) product manual, operation manual, maintenance manual, etc.

6.2.2 Test equipment and instruments

6.2.2.1 Equipment

The equipment including dedicated equipment shall be verified and calibrated within the validity period and meet the following requirements.

a) Accumulator loading device: control the launch speed of UA by adjusting the dynamic pressure. The adjustable range of the speed shall be at least 0 m/s to 25 m/s, in which the error shall be within ±0,1 m/s in the range of 0 m/s to 5 m/s and within ±0,5 m/s in the range of 5 m/s to 25 m/s.

b) Speed measuring device: measure actual impact speed of UA. The accuracy of the speed measurement shall be controlled within ±0,1 m/s.

c) High speed camera: record the motion and response of blades after impact. The shooting frame rate shall be ≥ 1 000 frames per second.

d) Target fixture: adjust the installation position and angle of bionic skin. The precision of the installation position shall be ±1 mm and that of the installation angle shall be ±1°.

e) Bionic skin: the length and width of the used bionic skin shall be no less than 1,5 times of the tested UA rotor blades. The bionic skin consists of a surface layer of skin and an underlying layer of foam. The surface skin is used to simulate the surface tissue of human skin; and the surface skin shall be able to afford the puncture force of 2 N. The lower layer of foam is used to imitate fat and muscle, and the specification of the lower layer of foam: the material is expanded polypropylene; the density is 30 g/l.

6.2.2.2 Test Instruments

The instruments shall be verified and calibrated within the validity period and meet the following requirements.

a) Dimension measuring tool: measure the maximum surface length and maximum depth of the wounds with an accuracy of ±0,5 mm.

b) Rotational speed measuring instrument: measure the rotational speed of blades with an accuracy of ±2,5 %.

6.2.2.3 Test articles

The test articles shall meet the following requirements.

a) The test articles shall conform to the contents of the submitted product information.

b) Inspections shall be conducted to the blades that are free with any cracks, unfilled corners and other defects.

c) The rotational speed of rotor blades during the tests shall be maintained at the maximum speed in the operations. In order to do so, the battery of the UA should be fully charged before the test.

6.3 Test site

The tests should be conducted at indoor sites.

6.4 Test environment

Unless otherwise specified, the tests shall be conducted under the following conditions:

a) temperature: 21 °C ± 2 °C;

b) relative humidity: 20 % to 80 %;

c) air pressure: 84 kPa to 106 kPa.

6.5 Test staff

The test operator should be able to operate the testing devices, measuring equipment and specimens proficiently.

6.6 Test interruption and resumption

The procedures of the test interruption and resumption are as follows.

a) Tests should be interrupted in case of the following circumstance:

   1) the key indicators, such as the rotational speed and quality of specimens, are unqualified;

   2) the specimens cannot work properly due to any irreparable malfunction;

   3) the test environments cannot satisfy the requirements for the evaluation conditions.

b) Tests can be resumed under the following conditions:

   1) individual test items are not qualified, but the faults have been found and corrected;

   2) potential safety hazards occur during evaluation, but the hazards have been eliminated;

   3) the configuration of specimens is reset to its initiate state by maintenance and adjustment;

   4) components deteriorating the technical performance of specimens have been replaced.

6.7 Test evaluation report

Unless otherwise specified, a test evaluation report shall include the following content:

a) product models, samples and supplier information;

b) photos of a general view of specimens;

c) title, site, purpose and basis;

d) project, sequence, date, and staff;

e) calibrations of the equipment and instruments;

f) photographic records of evaluation;

g) evaluation results and description;

h) test data, data processing methods and processing results;

i) evaluation conclusions.

7 Evaluation content

Unless otherwise specified, the evaluation content shall include the following information:

a) impact speed of specimens;

b) rotational speed of blades;

c) impact attitude of specimens;

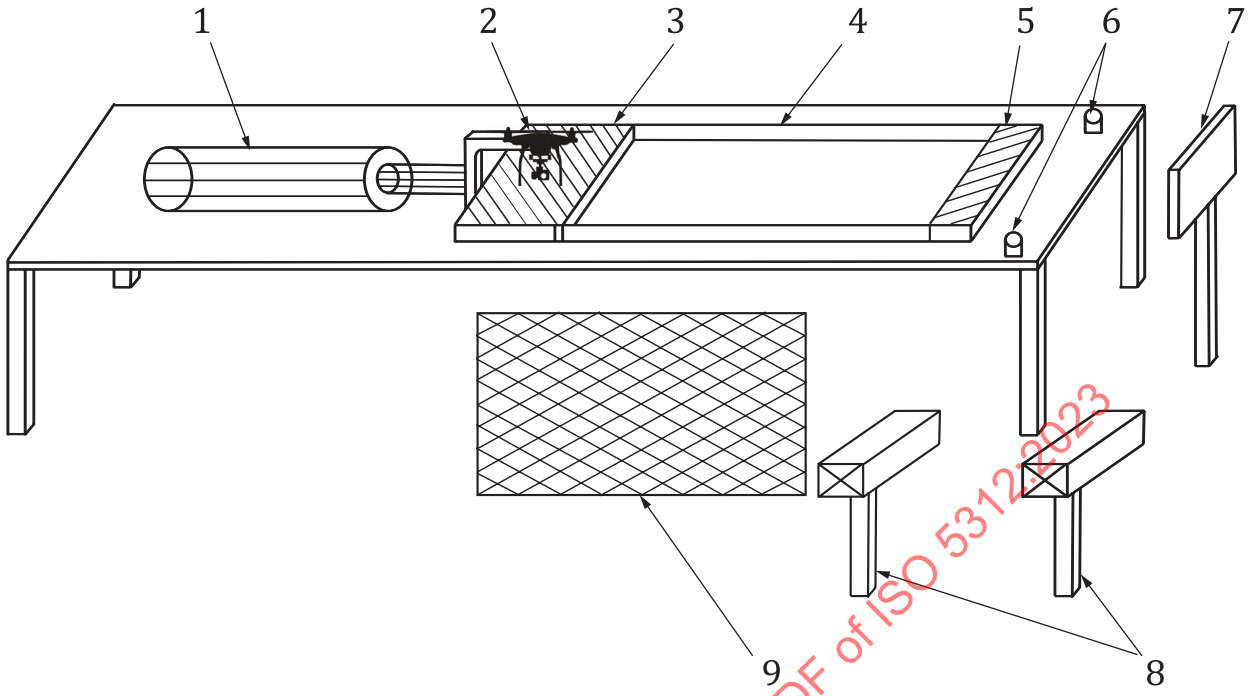
d) laceration length of bionic skin;

e) puncture depth of bionic skin.

8 Evaluation tests

8.1 Test principle

The test facility is illustrated in Figure 2, which is combined with energy accumulator, test article holder device basement, slide rail, buffer block, UA launching speed measuring device, target fixture, high-speed cameras and surrounded protection device. Before the test, the test article is assembled on the holder, with a perpendicular angle to its launching direction. After setting up the testing facilities, start UA rotors to their target speeds; then launch the test article with a given speed to the target. The device basement hits the buffer block at the end of the slide rail; and the UA is subjected to inertia and flies forward along the slide rail direction. In the period that the test article passively flies to the target, the impact progress can be recorded with the speed measuring device and the high-speed cameras. If a whole UA cannot be mounted to the holder, the UA can be replaced by a test article with self-rotating motors equipped with rotor blades, with the satisfactions of the mass of the test article and rotational speed of the self-rotating motor consistent with the whole UA.



Key

1 energy accumulator
2 test article holder
3 device basement
4 slide rail
5 buffer block
6 UA launching speed measuring device
7 target fixture
8 high-speed cameras
9 surrounded protection device.

Figure 2 — Schematic of the accumulating loading impact test

8.2 Test preparation

8.2.1 Test checklist

Unless otherwise specified, the checklist shall include the following content:

a) the appearance, configuration, quantity and photographing record of specimens;

b) the test site and environment shall meet the requirements;

c) the equipment and instruments shall work functionally;

d) the test procedure, test status, test parameter and test record shall meet the requirements.

8.2.2 Test installation

Installation of the test article driven by the UV holder shall meet the following requirements.

a) Bionic skin: fixed on a target fixture with rigid plane, of which position is perpendicular to the UA blades flight direction and rotor rotation plane.

b) The UA and rotor blades: the UA with its rotor blades shall be installed on the UV holder with restraint devices. The UA with its rotor blades shall be stable enough to avoid any slip to the holder.

c) High-speed cameras: at least one high-speed camera shall be installed near to the impact point of the bionic skin.

d) Surrounded protection device: install test protection net or other protective device on the side of the tester to protect the UA and tester from additional damage.

8.3 Test procedures

The accumulating loading impact test shall be conducted in following steps:

a) adjust the accumulator loading device to obtain the loading parameters under the required working conditions, and adjust the speed measuring device and the high-speed camera;

b) adjust the installation location and posture of the test article to align the impact direction with the impact point;

c) adjust the target fixture so that the UA blades rotation plane and the UA motion direction are perpendicular to the bionic skin;

d) prepare the loading according to the adjusted parameters to ensure that the final launch speed is equivalent to 25 % of the maximum flight speed; and adjust the rotational speed of blades to their target speeds and confirm the rotating speeds via tachometer.

e) start the test when ready;

f) safety officer, operator and commander reset all equipment to their initial state;

g) save the data from the measuring equipment and high-speed camera, and clean up the site;

h) record the deformation and damage of the specimens and the data of the length of the laceration and the depth of the puncture; fill in a record form;

i) repeat steps e) to h) under the same loading conditions to obtain three valid data;

j) reset the accumulator loading device by adjusting parameters to ensure that the final launch speed is equivalent to 50 % of the maximum flight speed, and adjust the rotational speed of blades accordingly;

k) repeat steps e) to h) under the same loading conditions to obtain three valid data;

l) reset the accumulator loading device by adjusting parameters to ensure that the final launch speed is equivalent to 75 % of the maximum flight speed; and adjust the rotational speed of blades accordingly;

m) repeat steps e) to h) under the same loading conditions to obtain three valid data;

n) reset the accumulator loading device by adjusting parameters to ensure that the final launch speed is equivalent to 100 % of the maximum flight speed; and adjust the rotational speed of blades accordingly;

o) repeat steps e) to h) under the same loading conditions to obtain three valid data.

8.4 Post-test inspection

Inspect the structure and function of the specimens after testing; and record the inspection results.