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Civil small and light unmanned aircraft (UA) — Sharp injury to human body by rotor blades — Evaluation and test method ~~of rotor blade sharp injury to human body for civil lightweight and small UA~~

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

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, ~~light~~small and ~~small~~light UA increases significantly, becoming the majority of civil UA. At present, the civil small and light ~~and small~~ 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 ~~and small~~ 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 ~~and small~~ 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 ~~and small~~ 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 ~~and small~~ 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 ~~and small~~ UA, thereby improving the safety of the product.

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

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

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

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

Civil small and light unmanned aircraft (UA) — Sharp injury to human body by rotor blades — Evaluation and test method ~~of rotor blade sharp injury to human body for civil lightweight and small UA~~

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 ~~and small~~ 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 ~~light~~small and ~~small~~light UA (with maximum take-off mass between 0,25 kg to 4 kg, which are between the scale 2 and 3 ~~categorised~~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~~:2020~~, *Categorization and classification of civil unmanned aircraft systems*

~~ISO 21384-4:2020, *Unmanned aircraft systems — Part 4: Vocabulary*~~

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~~(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.~~.

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

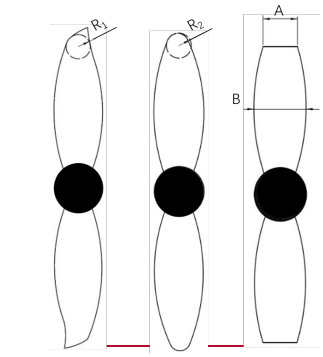
The requirements for sharp damage to the human body by the rotor blades of civil small and light ~~and small~~ UA are divided into analysis levels and test levels; and it is sufficient to meet either. The details of analytical levels are shown in Table 2~~Table 2,;~~ and the ~~ones~~details of test levels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

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

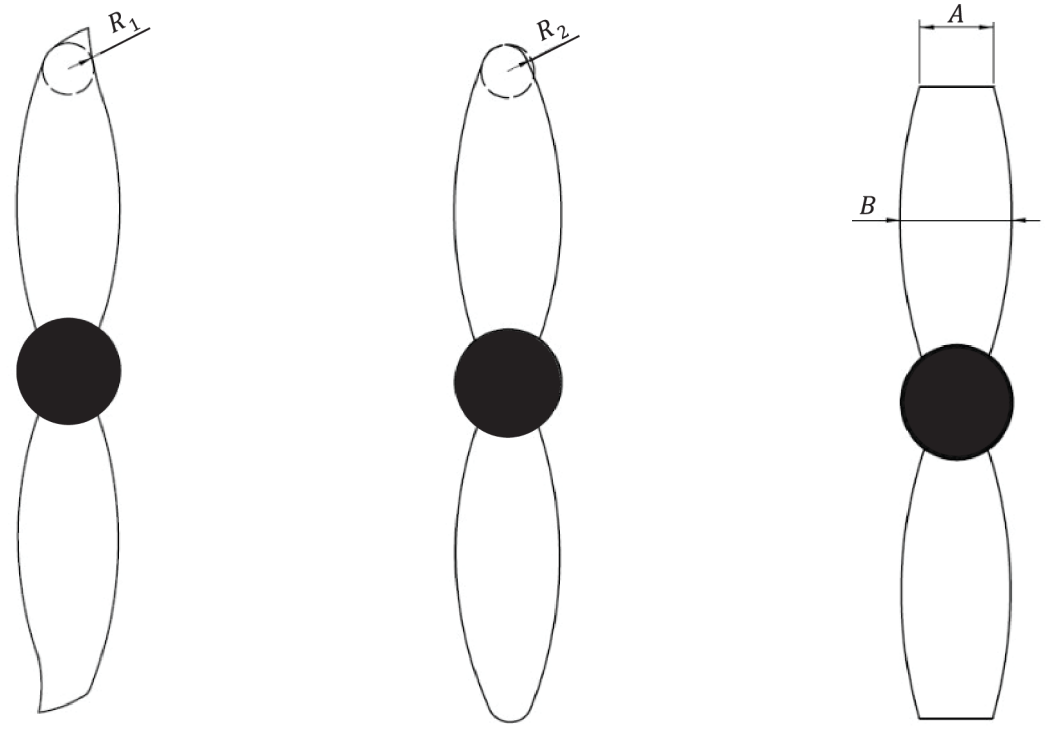
b) ~~b)~~ a rounded propeller tip shall not have a radius R_2 of less than 1 mm [Figure 1~~(Figure 1, middle);~~, b)];

c) ~~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~~(Figure 1, right);~~, c)];

d) ~~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) b) c)~~



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

Figure 2 1 — Blade geometry

As shown in Tables 2Tables 2 and 33, it is acceptable when the injury is on the level 1 or level 2. It is unacceptable when the injury is on the level 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)

$K = 6\cdot 10^{-7}(m r^2 N^2)$, 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) ~~a)~~ design documents, drawings and interface documents that related to the tests;

b) ~~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) ~~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,~~5m~~5 m/s in the range of 5 m/s to 25 m/s.

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

e) ~~e) bionic~~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 ~~30g/L~~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) ~~a)~~ Dimension measuring tool: measure the maximum surface length and maximum depth of the wounds with an accuracy of ±0,5 mm.

b) ~~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 ~~be met~~meet the following requirements.

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

