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Evaluation method for the resonance frequency of the multi-copter UA (unmanned aircraft) by measurement of rotor and body frequencies

Méthode d'évaluation de la fréquence de résonance du multicoptère télépiloté par mesure des fréquences du rotor et du corps

Reference number
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Foreword

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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.

Introduction

This document defines the correlation between the excitation frequency caused by rotor rotation and the resonance frequency of the main body in the design of the multi-copter UA (unmanned aircraft), and suggests the evaluation method to define the design requirements of the multi-copter UA to prevent damage due to resonance.

Typical applications for evaluation of resonance of the UA are:

a) measuring the natural frequency of the UA;

b) measuring the thrust forces and the rotational frequency of the rotor;

c) determining the modal properties of the UA (natural frequency, damping and mode shape);

d) checking the resonance between the natural frequency of main body and the rotational frequency of the rotor.

Evaluation method for the resonance frequency of the multi-copter UA (unmanned aircraft) by measurement of rotor and body frequencies

1 Scope

This document provides a method for evaluating the resonance vibration frequency of the multi-copter unmanned aircraft (UA). This document specifies a method of designing the UA so as to avoid the resonance generated by the coincidence of the natural frequency of the UA body and the rotational frequency of the rotor.

This document is applicable to multi-copter UA weighing less than 150 kg.

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.

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-64, *Environmental testing - Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance*

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
operating frequency range
rotation frequency span between the lowest frequency to the highest frequency of an unmanned aircraft (UA) to fly

3.2
natural frequency
frequency or rate at which an unmanned aircraft (UA) vibrates naturally when disturbed

Note 1 to entry: The natural frequency changes when the mass distribution (e.g. adding a payload) changes, it is measured with the added payload.

3.3
resonant frequency
phenomenon in which an external force or a vibrating system forces another system around it to vibrate with greater amplitude at a specified frequency of operation

3.4
frequency response function
function that represents the relationship between an input signal and an output signal in the frequency domain

3.5
FFT
fast Fourier transform
algorithm that computes the discrete Fourier transform (DFT) of a sequence

Note 1 to entry: Fourier analysis converts a signal from its original domain (often time or space) to a representation in the frequency domain and vice versa.

3.6
arming frequency
rotating frequency of the propeller before take-off

4 Test method

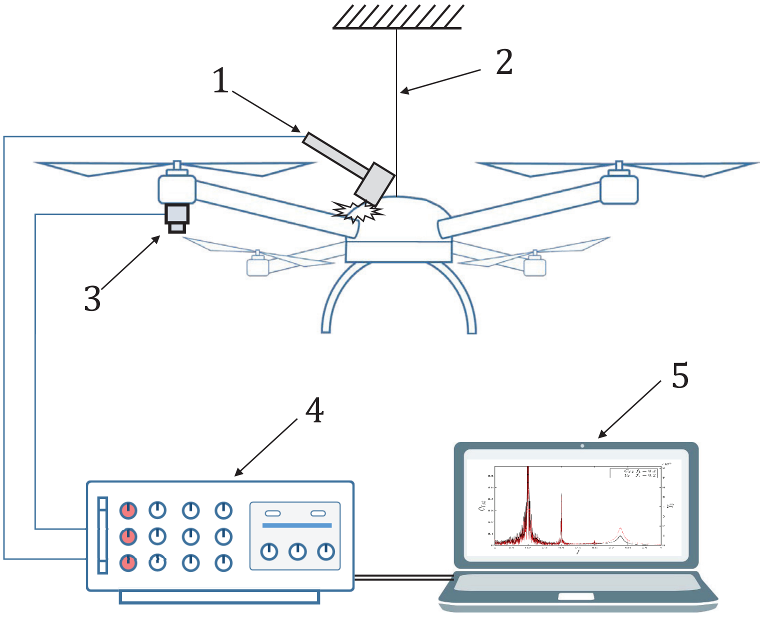
4.1 Test setup

4.1.1 General

In the case of a small-sized UA, the impact hammering method is simple; it has good cost-effectiveness and is often used to measure the natural frequency of small structures. In the case of a large-sized UA, if an impact hammer is used, the energy transfer is small and accurate measurement may not be possible. In such a case, the natural frequency and the natural mode shape can be measured using an exciter. The method to use depends on the size, shape, and material of the UA; so it is determined by previous experiences. It may also be possible to measure the vibration profiles for the larger UA, depending on the size of the test article, by using the hammering excitation method.

4.1.2 Hammering method

Figure 1 and Figure 2 show the concept of the test device for measuring the natural frequency and the natural-mode shape. To measure the natural frequency, the UA is typically suspended in the air using a wire or placed on a sponge. At this time, in order not to affect the natural frequency of the wire's stiffness, it is enough to have the minimum strength to hang UA. The sponge should also be soft, if possible, in order not to affect the natural frequency. A previous analysis shall be done so as to determine the natural frequencies, which should be far away in order not to affect the natural frequencies of the UA (estimated previously). Since the stiffness of the blade is very small compared to the stiffness of the frame, the direction of the blade is not so important in small UA. However, it is better placing the blades in such that direction of them is perpendicular to each arm.



Key

1 impact hammer

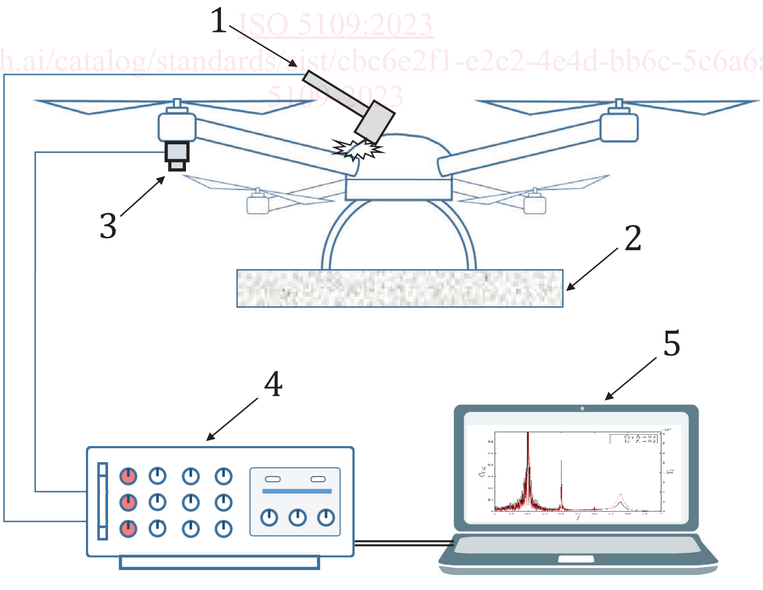
2 wire

3 accelerometer

4 amplifier

5 signal analyser

Figure 1 — Schematic diagram of measuring the natural frequency using a wire (small-sized UA)



Key

1 impact hammer

2 sponge

3 accelerometer

4 amplifier

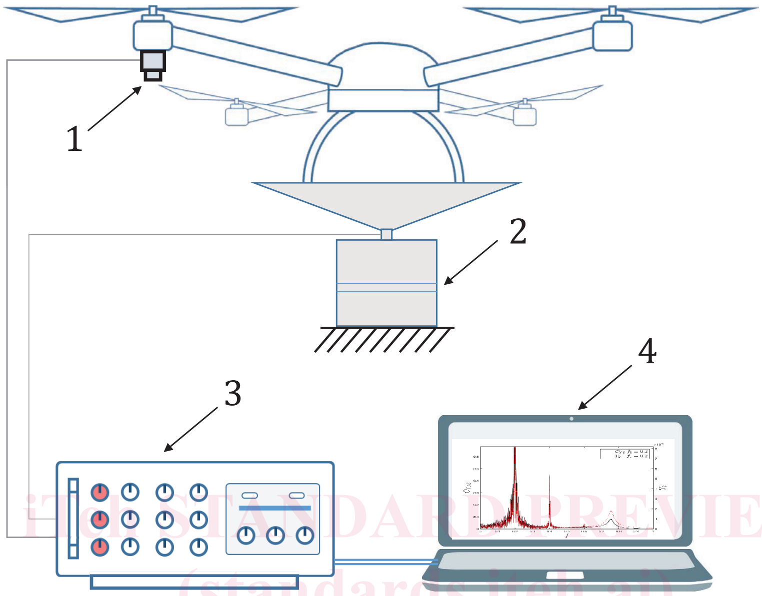
5 signal analyser

Figure 2 — Schematic diagram of measuring the natural frequency using a sponge (small-sized UA)

NOTE Details of support systems are given in Section 7.5 of ASTM E1876-01.

4.1.3 Excitation table method

For a large UA, it should be placed on the vibrator during the measurement. The resonance frequency of the UA using the vibrator shall be measured according to IEC 60068-2-6 or IEC 60068-2-64. Figure 3 shows the measurement on the vibrator. In this test, the natural frequency and natural mode shape of the UA are measured. In order to measure the natural frequency of the UA, the accelerometer shall be attached to the UA and the measurement shall be taken in several places. A 3-axis accelerometer should be used.



Key

1 accelerometer
2 vibrator
3 amplifier
4 signal analyser

Figure 3 — Schematic diagram of measuring the natural frequency (large-sized UA)

4.2 Concept of an operation frequency

Figure 4 shows the schematic diagram of the device for measuring the rotor speed and the thrust force. The purpose of this test is to measure the thrust force caused by the rotational speed of the UA rotor. For a small-sized UA, it is difficult to take the measurement with a tachometer as the motor rotates at a high speed; a microphone should be used in this case. For a large-sized UA, a tachometer should be used.