INTERNATIONAL STANDARD

ISO 16063-32

First edition
2016-09-15

Methods for the calibration of vibration and shock transducers —

Part 32: Resonance testing — Testing the frequency and the phase response of accelerometers by means of shock excitation

Méthodes pour l'étalonnage des transducteurs de vibrations et de chocs —

Partie 32: Essais de résonance — Essai de la fréquence et de la réponse de phase des accéléromètres au moyen d'excitations par chocs

Reference number
ISO 16063-32:2016(E)

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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 documents 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

This first edition of ISO 16063-32 cancels and replaces the first edition of ISO 5347-14:1993, which has been technically revised.

ISO 16063 consists of the following parts, under the general title *Methods for the calibration of vibration and shock transducers*:

— *Part 1: Basic concepts*

— *Part 11: Primary vibration calibration by laser interferometry*

— *Part 12: Primary vibration calibration by the reciprocity method*

— *Part 13: Primary shock calibration using laser interferometry*

— *Part 15: Primary angular vibration calibration by laser interferometry*

— *Part 16: Calibration by Earth's gravitation*

— *Part 17: Primary calibration by centrifuge*

— *Part 21: Vibration calibration by comparison to a reference transducer*

— *Part 22: Shock calibration by comparison to a reference transducer*

— *Part 31: Testing of transverse vibration sensitivity*

— *Part 32: Resonance testing — Testing the frequency and the phase response of accelerometers by means of shock excitation*

— *Part 41: Calibration of laser vibrometers*

— *Part 42: Calibration of seismometers with high accuracy using acceleration of gravity*

— *Part 43: Calibration of accelerometers by model-based parameter identification*

The following parts are under preparation:

— *Part 33: Testing of magnetic field sensitivity*

Methods for the calibration of vibration and shock transducers —

Part 32: Resonance testing — Testing the frequency and the phase response of accelerometers by means of shock excitation

1 Scope

This part of ISO 16063 lays down detailed specification for instruments and procedures of testing the frequency and the phase response of accelerometers by means of shock excitation. It applies to the accelerometers of the piezoelectric, piezoresistive and variable capacitance types with the damping ratio less than critical and in the frequency range up to 150 kHz.

The method presumes that the frequency and the phase responses of the accelerometer under test gained by this method are the best possible characteristics for the mounted accelerometer on the condition that the recommendations for mechanical mounting of accelerometer stated in ISO 5348 are fulfilled and that the mass of the reference shock ball exceeds at least three times the mass of the accelerometer under test.

Phase response of the accelerometer under test gained by this method is considered to be some "virtual" characteristic of accelerometer presuming that there is zero phase shift between the input and output signals at a frequency of 0 Hz.

NOTE 1 It is intended that the user be aware that for the same accelerometer in the field application, the frequency and the phase responses might be different, depending on the mass and compliance of the test structure and the method of mounting. The method allows just a qualitative evaluation of the frequency and the phase response of accelerometers.

NOTE 2 It is intended that the user does not try to get better resolution of the initial parts of the frequency and phase responses of the accelerometer under test than the dynamic range of the adequate characteristic provides it. The best use of the frequency and the phase responses of the accelerometer gained by this method are to get the best fit lines for the initial parts of the mentioned characteristics.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For updated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 5347-22, *Methods for the calibration of vibration and shock pick-ups — Part 22: Accelerometer resonance testing — General methods*

ISO 5348, *Mechanical vibration and shock — Mechanical mounting of accelerometers*

3 Factors influencing measurement reproducibility

The limits of the uncertainty of the frequency response measurement shall be as follows.

For the resonance frequency of the accelerometer under test, the absolute uncertainty is equal to the frequency analysis resolution and is an inverse value relative to the time-record length of the accelerometer signal. The recommended minimum number of lines in the frequency domain for this method is 400. Assuming that the resonance frequency is in the middle of the frequency span, the standard uncertainty for the resonance frequency is about 0,5 %.

NOTE 1 This uncertainty is presumed to have a uniform distribution within the frequency resolution band.

For the damping ratio of the accelerometer under test, the uncertainty is dependent on the signal-to-noise ratio of the measurement in a time domain.

Assuming that the measurements are carried out so that the maximum signal value is close to the upper limit of the dynamic range of measuring instrument and that the typical damping ratio for the piezoelectric accelerometers is about 0,01, the standard uncertainty for the damping ratio measurements is about 1 %.

NOTE 2 The signal analyser used for the damping ratio measurements is supposed to have at least an 80 dB dynamic range.

For the phase response of the accelerometer under test, the absolute uncertainty is equal to the amplitude resolution in phase; that means resolution in the amplitude of the measuring instrument, corrected by the phase noise suppression procedure for the unwrapped phase. For a typical 40 dB phase noise suppression, the resulting resolution in phase appears to be about 1 % or about 5° in phase domain.

The mentioned uncertainties are the lowest values provided by the instruments, used for the acquisition of the time signal and the frequency analysis. The expanded uncertainties can be larger, depending on the complexity of the frequency response of the accelerometer under test.

NOTE 3 To prove the robustness of the measurements of the resonance frequency and damping ratio of the accelerometer under test, multiple measurements can be carried out.

4 Apparatus and other devices

4.1 Environmental conditions

The equipment shall be capable of maintaining the following environmental conditions:

— room temperature (23 ± 5) °C;

— relative humidity should be less than 90 %.

4.2 Reference shock ball

4.2.1 General

A reference shock ball for mounting an accelerometer under test shall be made of steel hardened to more than HRC50 and polished.

NOTE A typical ball from a ball bearing is very convenient to answer this requirement.

4.2.2 Reference shock ball dimensions

The reference shock ball shall have a flat surface with a thread to mount the accelerometer under test (see Figure 1).

4.2.3 Options for the reference shock ball diameter range

The requirements related to the actual dimensions to the shock balls are not very strict.

On one hand, the diameter of the shock ball shall be small enough to provide its highest possible natural frequency.

On the other hand, the diameter of the shock ball shall be large enough to get a mass of the reference shock ball that exceeds three times the mass of the accelerometer under test.

From the practical point of view for the majority of the accelerometers, the diameters of two balls are preferable:

— a ball with the dimensions D = 32 mm, B = 20 mm, L = 10 mm for the accelerometers with the natural frequencies lower than 100 kHz;

— a ball with the dimensions D = 19 mm, B = 10 mm, L = 7,5 mm for the accelerometers with the natural frequencies lower than 150 kHz.

Other possible dimensions of the ball may also be used for the purpose of this test.

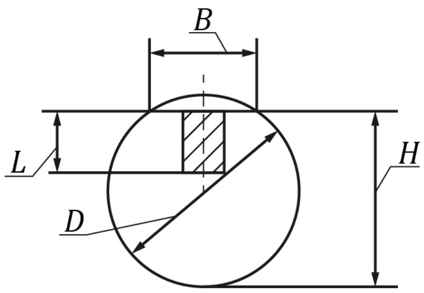

Figure 1 — Reference shock ball dimensions

NOTE 1 The following formulae can be used to calculate the natural frequencies of the ball.

The natural frequency of the first rotatory resonance of the ball can be calculated from Formula (1):

$$f_{\text{ball}} = 1{,}834\,6 \times \frac{c_{\text{S}}}{D} \tag{1}$$

where c_{S} is the velocity of the shear waves in steel (3 251 m/s).

The natural frequency of the first radial resonance of the ball can be calculated from Formula (2):

$$f_{\text{ball}} = 0{,}816\,0 \times \frac{c_{\text{D}}}{D} \tag{2}$$

where

c_{D} is the velocity of dilatation waves in steel (5 941 m/s);

D is the diameter of the ball.

The natural frequency of the first longitudinal resonance of the ball can be calculated from Formula (3):

$$f = 0{,}5 \times \frac{c_{\text{E}}}{H} \tag{3}$$

where c_{E} is the velocity of the extension waves in steel (5 250 m/s).

In practice, only Formula (3) provides the lowest frequency of the ball's resonance and has to be taken into account.

The shock pulse duration that is provided by this method is usually fairly large compared to the period of the natural oscillations of the ball. That is why the natural resonances of the ball are not usually induced when using this method. Moreover, the accelerometer under test typically dampens the higher resonances