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Methods for the calibration of vibration and shock transducers —

Part 22: Shock calibration by comparison to a reference transducer

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

Partie 22: Étalonnage de chocs par comparaison à un transducteur de référence

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 16063-22 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

This first edition cancels and replaces ISO 5347-4:1993, 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 21: Vibration calibration by comparison to a reference transducer*
- *Part 22: Shock calibration by comparison to a reference transducer*

Methods for the calibration of vibration and shock transducers —

Part 22:
Shock calibration by comparison to a reference transducer

1 Scope

This part of ISO 16063 specifies the instrumentation and procedures to be used for secondary shock calibration of rectilinear transducers, using a reference acceleration, velocity or force measurement for the time-dependent shock. The methods are applicable in a shock pulse duration range[1] of 0,05 ms to 8,0 ms, and a dynamic range (peak value) of 100 m/s^2 to 100 km/s^2 (time-dependent). The methods allow the transducer shock sensitivity (i.e. the relationship between the peak values of the transducer output quantity and the acceleration) to be obtained.

These methods are not intended for the calibration of dynamic force transducers used in modal analysis.

NOTE 1 This part of ISO 16063 is aimed at users engaged in shock measurements requiring traceability as stated in ISO 9001 and ISO/IEC 17025.

NOTE 2 The methods specified in this part of ISO 16063 are based on the measurement of the time history of the acceleration. These methods fundamentally deviate from another shock calibration method that is based on the principle of the change in velocity, described in ISO 16063-1. The shock sensitivity therefore differs fundamentally from the shock calibration factor obtained by the latter method, but is in compliance with the shock sensitivity stated in ISO 16063-13.

2 Normative references

The following referenced documents are indispensable for the application 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, *Vibration and shock — Vocabulary*

ISO 5347-22, *Methods for the calibration of vibration and shock pick-ups — Part 22: Accelerometer resonance testing — General methods*[2]

ISO 16063-1:1998, *Methods for the calibration of vibration and shock transducers — Part 1: Basic concepts*

ISO 18431-2, *Mechanical vibration and shock — Signal processing — Part 2: Time domain windows for Fourier Transform analysis*

1) In exceptional cases, shorter or longer shock pulse durations are possible.

2) Under revision to become a part of ISO 16063.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041 and the following apply.

3.1
peak value
maximum value of the magnitude or absolute value of the shock pulse

4 Uncertainty of measurement

The limits of the uncertainty of shock sensitivity measurement are as shown in Table 1.

Table 1 — Uncertainty reference conditions for secondary shock calibration

Shock calibrator apparatus	Acceleration peak magnitude[a] km/s^2	Minimum pulse duration[a,b] ms	Uncertainty limit
Pendulum	1,5	3	5 %
Dropball	100	0,100	5 %
Pneumatically operated piston	100	0,100	5 %
Hopkinson bar with velocity comparison	100[c]	0,050[c]	10 %
Hopkinson bar with acceleration comparison	100[c]	0,050[c]	6 %
Split Hopkinson bar with force comparison	100[c]	0,050[c]	10 %

[a] Variations in peak values and duration = ±10 %.

[b] Pulse duration is measured at 10 % of the peak value (see Clause 7).

[c] Larger accelerations (peak values) and shorter pulse durations are possible but without reference to primary methodologies.

The uncertainty of measurement is expressed as the expanded relative measurement uncertainty in accordance with ISO 16063-1 (briefly referred to as “uncertainty”). The specified uncertainties are based on a coverage factor k = 2 that is a coverage probability of about 95 %.

The uncertainty specifications of Table 1 can be achieved as long as the spectral energy produced by the excitation of any mode of resonance inherent in the transducer or shock machine structure during calibration is small relative to the spectral energy contained in the frequency range of calibration. The transducer resonance testing shall be performed in accordance with ISO 5347-22.

NOTE For the calibration of transducers of high accuracy (e.g. reference transducers) and if great care is taken to keep all uncertainty components small enough to comply with the specifications (see uncertainty budgets in Annex A), smaller uncertainties than stated in Table 1 may be achievable. For the pendulum shock calibrator, the dropball shock calibrator and the pneumatically operated piston shock calibrator, an uncertainty of 1 % has been obtained in an interlaboratory comparison covering acceleration peak values from 200 m/s^2 to 2 000 m/s^2 [1].

The acceleration peak magnitude may be expressed in terms of the standard acceleration due to gravity, symbol g_n (1 g_n = 9,806 65 m/s^2; 1,5 km/s^2 ≈ 150 g_n).

The shortest shock duration applicable to a transducer according to the manufacturer’s specification shall be taken into account to avoid increasing the measurement uncertainty and damaging or destroying the transducer.

5 Apparatus

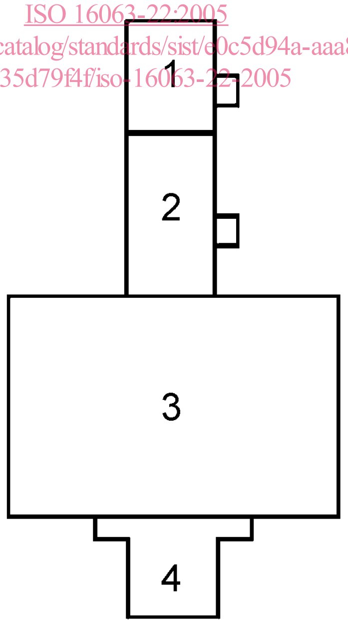
5.1 General considerations

All surfaces on which transducers (the reference or the transducer under test) are mounted shall be polished, flat and clean. The surface on which the transducer is to be mounted shall have a roughness value, expressed as the arithmetical mean deviation, Ra, of less than 1 µm. The flatness shall be such that the surface is contained between two parallel planes 5 µm apart, over the area corresponding to the maximum mounting surface of any transducer to be calibrated. The drilled and tapped hole for connecting the transducer shall have a perpendicularity tolerance to the surface of less than 10 µm; i.e. the centreline of the hole shall be contained in a cylindrical zone of 10 µm diameter and a height equal to the hole depth. Appropriate screw and bolt torque may be found in numerous references and are chosen according to the mounting surface material. The recommendations of the transducer manufacturer shall be followed in all cases.

5.2 Anvil shock calibrators (100 m/s^2 to 100 km/s^2)

5.2.1 General considerations

This clause gives recommended specifications for the anvil shock calibrators to obtain the uncertainties of Clause 4. When back-to-back calibrations are performed with the dropball shock calibrator or the pneumatically operated piston shock calibrator, it is recommended that the transducer under test be mounted directly on top of the reference transducer as shown in Figure 1. This mounting is not recommended for pendulum shock calibrators, see 5.2.2 and Figure 3. For best accuracy, test transducers and mounting fixtures should not have dimensions or masses significantly greater than that of the reference transducer because the sensitivity and frequency response of the reference transducer will vary slightly depending on the amount of mass attached. For all methods, the natural period of the test transducer, equal to the inverse of the resonance frequency, shall be less than 0,2 times the half-sine pulse duration of the applied shock pulse to eliminate excessive overshoot and “ringing” due to resonance excitation.



Key

1 test transducer

2 reference transducer

3 test mass

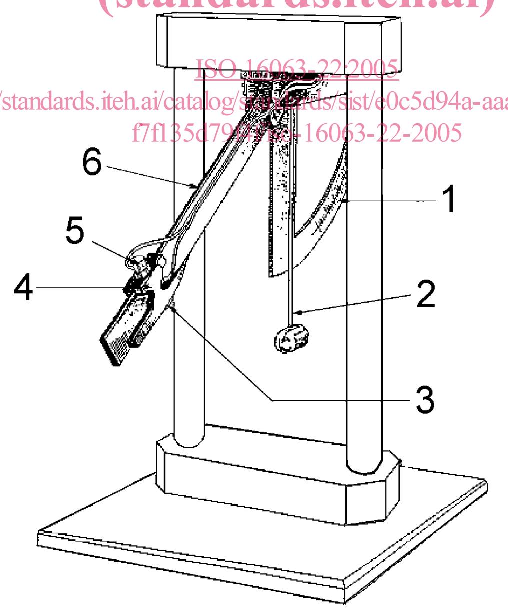
4 anvil

Figure 1 — Recommended mounting of transducers, anvil and test masses

5.2.2 Pendulum shock calibrator

The pendulum shock calibrator provides an assessment of the shock sensitivity and magnitude linearity for transducers and a means of calibrating large quantities of transducers. Comparison calibrations are performed at accelerations ranging from 100 m/s^2 to 1 500 m/s^2 (10 g_n to 150 g_n) at half-sine pulse durations (measured at 10 % magnitude) from 3 ms to 8 ms. A schematic diagram of the pendulum shock calibrator is shown in Figure 2. The shock pulse duration, T, is dependent on the acceleration peak value, i.e. 3 ms at 1 500 m/s^2 and 8 ms at 100 m/s^2. Amplitude linearity may be measured over 4 to 7 impacts of the pendulum system, or with a number of single shock pulses at different acceleration magnitudes.

The pendulum shock calibrator consists of a rigid frame, a hammer pendulum and an anvil pendulum. Typical dimensions for the frame are approximately 500 mm by 500 mm for the square base plate and 780 mm height. The mass of the whole construction is approximately 60 kg. The length of anvil pendulum is approximately 400 mm. Shifting the hammer pendulum to the desired angular displacement and dropping it can excite an impact from the hammer pendulum to the anvil pendulum. An angular scale, graduated in degrees, is provided for determining the angular displacement of the hammer pendulum. The maximum velocity change during the impact phase is less than 3 m/s. A reference transducer and a test transducer are mounted on the pendulum as shown in Figure 3. A scale, graduated in degrees, is provided for angular displacement of the hammer pendulum. Both pendulums have approximately the same moment of inertia to give a series of impacts with decreasing amplitude. A rubber pad between the two pendulums transmits the impact with a known pulse shape from one pendulum to the other. The hardness of the rubber pad determines the pulse shape and duration as well as the number of applicable impacts. To create a haversine pulse shape, typical butadiene rubber pad specifications are 8 mm thickness and 56 Shore A hardness. The test and reference transducers are located at the nodal point for the first axial mode of the anvil pendulum to prevent structural vibrations from contaminating the data. It is recommended that the centre of gravity for the seismic mass of the transducer under test be aligned with the sensitive axis of the reference transducer at the anvil pendulum by means of a mounting stud or other optional mounting adapters [15].



Key

1 graduated scale with adjustable end stop

2 hammer pendulum

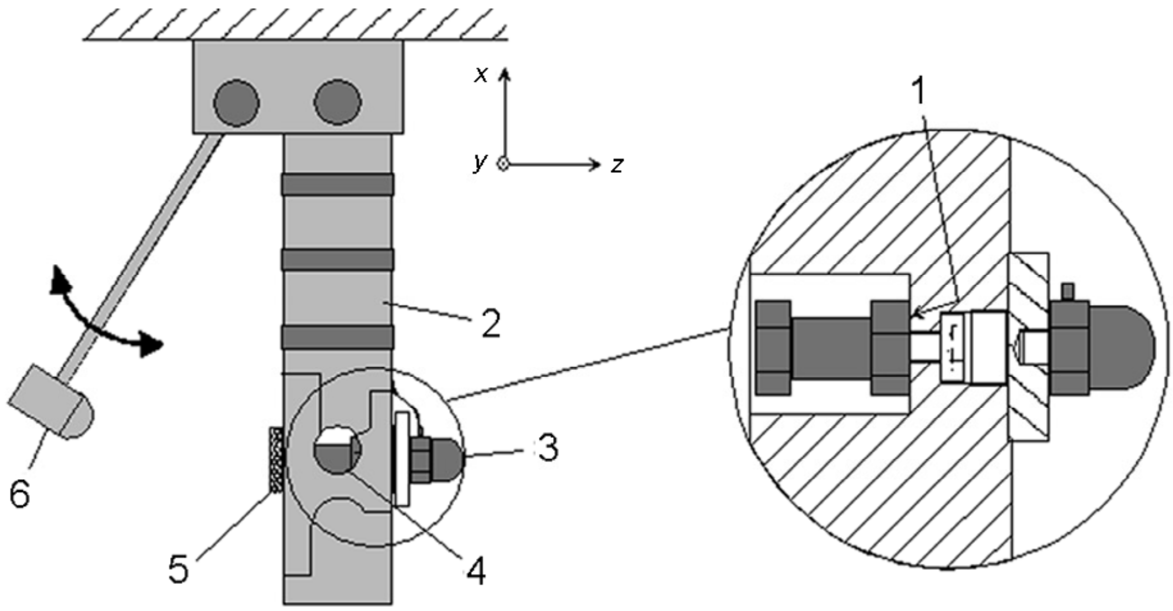
3 rubber pad

4 reference transducer

5 test transducer

6 anvil pendulum

Figure 2 — Example of a pendulum shock calibrator for transducer



Key

1 reference and measurement surface used for primary calibration

2 anvil pendulum

3 test transducer

4 reference transducer

5 butadiene rubber

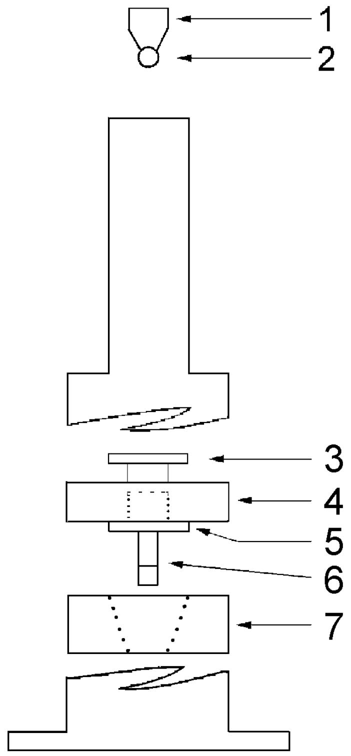
6 hammer pendulum

Figure 3 — Correct mounting of transducers and selection of the reference surface for the reference transducer for pendulum shock calibrator

5.2.3 Dropball shock calibrator

A dropball shock calibrator uses a reference transducer mounted back-to-back with the test transducer on a steel anvil as shown in Figure 4. Shock peak magnitudes of 100 m/s^2 to 100 km/s^2 with pulse durations of 0,100 ms to 10 ms are created with the dropball. The assembly is inserted inside the tube of the dropball apparatus with the transducers located on the bottom of the anvil. The anvil is held in place inside the tube magnetically. A vacuum chuck is used to position and release a steel ball bearing located on the top of the tube of the dropball apparatus, such that the ball strikes the centre of the anvil located inside the tube upon impact. Upon impacting the anvil, the ball creates a mechanical shock pulse and causes the anvil to fall freely into a foam rubber catch mechanism located below the magnetic chuck inside the tube of the calibration apparatus. The peak amplitude and duration of the shock pulse created by this collision can be controlled by varying the diameter and mass of the ball[2], and by varying the amount of damping provided by the material added to the impact surface of the anvil.

The dropball apparatus is used to determine sensitivity as a function of either the peak acceleration magnitude (g_n) or frequency[3]. Ideally, parameters should be varied to produce pulses that result in significant spectral energy in the frequency range of 5 kHz to 10 kHz, independent of peak amplitude. For example, the diameter of the anvils that produce pulses having peak acceleration amplitudes in the range of 100 g_n to 1 000 g_n is less than 25 mm. The purpose of the plunger is to prevent multiple collisions of the relatively small-diameter balls with the anvil after the initial impact. The use of small balls with a small-sized anvil to produce pulses has two advantages. First, the decrease in the mass of the anvil reduces the risk of damaging the transducers when the anvil impacts the catch mechanism. Secondly, the reduction in the size of the anvil increases the frequencies of its natural modes of resonance. The second factor is important in the determination of peak amplitudes in the time domain, since anvil resonance can significantly modulate the envelope of the mechanical shock pulse[3].



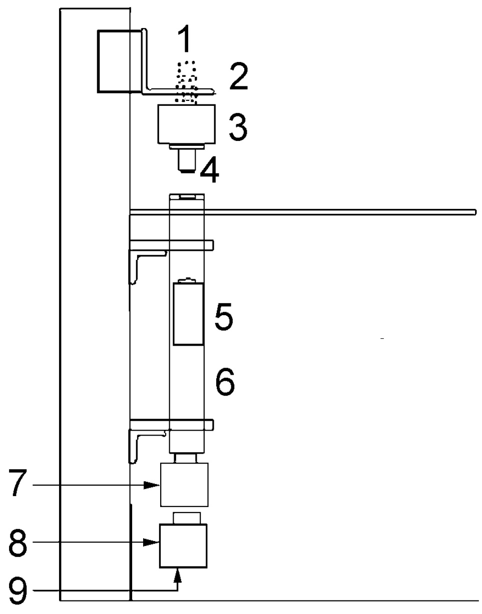
Key

1 vacuum chuck
2 steel ball bearing
3 plunger (optional)
4 magnetic chuck
5 anvil
6 transducers
7 catch mechanism

Figure 4 — Example of a dropball shock calibrator for transducer

5.2.4 Pneumatically operated piston shock calibrator

An upward moving pneumatically operated piston provides a simple, controllable and repeatable means of secondary shock calibration of transducers and is shown schematically in Figure 5[4]. Shock peak magnitudes of 200 m/s^2 to 100 km/s^2 (20 g_n to 10 000 g_n) at half-sine pulse durations from 100 µs to 3 ms, respectively, are created by the impact of a steel projectile on an anvil. Typical anvil materials are steel and aluminium. A reference transducer and a test transducer are mounted back-to-back on the anvil. A pressure regulator controls the pressure on the piston. A valve releases the pressure and provides precise control of the piston. When the impact occurs, the anvil lifts off a rubber mount, flies a short distance, and is stopped by a cushioned restraint. The piston is captive within a barrel. A wide range of pulse amplitudes and durations is created with pressure control and combinations of anvils, additional masses, and pad thickness.



Key

1 cushioned restraint

2 transducer under test and reference transducer

3 optional test mass

4 anvil and pad

5 piston

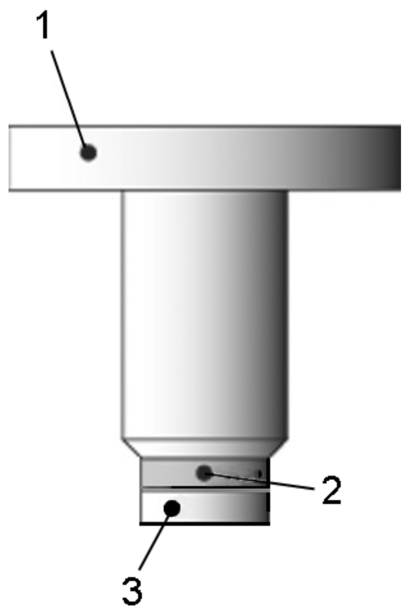
6 barrel

7 valve

8 pressure regulator

9 pressurized air source

a) Shock calibrator



Key

1 anvil

2 rubber pad

3 felt pad

b) Anvil and pad

Figure 5 — Schematic diagram for an upwardly moving pneumatically operated piston shock calibrator

Pads may be torn by high projectile velocity and large additional masses. Damaged pads create non-repeatable pulses and potentially, excessively large amplitudes. Pads shall always be inspected before use. Damaged padding, particularly if it allows metal-to-metal impact between the projectile and anvil, can generate potentially damaging accelerations with nearly any drive pressure.

The characteristics of a shock pulse in general are determined by

a) the velocity of the projectile,

b) the mass of the target (anvil and transducer assembly) and, most critically,

c) the deformation of material between them.

Projectile velocity is approximately proportional to the drive pressure. Anvil velocity (the area under the acceleration curve) is affected by the ratio of the target mass to the projectile mass. Target mass is the sum of the anvil mass, supplemental mass, any additional mounting fixture mass, and the masses of the standard reference and test transducer. The more flexible the material at the point of impact, the longer the duration of

