INTERNATIONAL STANDARD

ISO
5347-2

First edition
1993-12-15

Methods for the calibration of vibration and shock pick-ups —

Part 2:
Primary shock calibration by light cutting

Méthodes pour l'étalonnage de capteurs de vibrations et de chocs —
Partie 2: Étalonnage primaire de chocs par coupe de lumière

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.

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.

International Standard ISO 5347-2 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Sub-Committee SC 3, *Use and calibration of vibration and shock measuring instruments*.

ISO 5347 consists of the following parts, under the general title *Methods for the calibration of vibration and shock pick-ups*:

— *Part 0: Basic concepts*

— *Part 1: Primary vibration calibration by laser interferometry*

— *Part 2: Primary shock calibration by light cutting*

— *Part 3: Secondary vibration calibration*

— *Part 4: Secondary shock calibration*

— *Part 5: Calibration by Earth's gravitation*

— *Part 6: Primary vibration calibration at low frequencies*

— *Part 7: Primary calibration by centrifuge*

— *Part 8: Primary calibration by dual centrifuge*

— *Part 9: Secondary vibration calibration by comparison of phase angles*

— *Part 10: Primary calibration by high-impact shocks*

— *Part 11: Testing of transverse vibration sensitivity*

— *Part 12: Testing of transverse shock sensitivity*

— *Part 13: Testing of base strain sensitivity*

— *Part 14: Resonance frequency testing of undamped accelerometers on a steel block*

— *Part 15: Testing of acoustic sensitivity*

— *Part 16: Testing of mounting torque sensitivity*

— *Part 17: Testing of fixed temperature sensitivity*

— *Part 18: Testing of transient temperature sensitivity*

— *Part 19: Testing of magnetic field sensitivity*

— *Part 20: Primary vibration calibration by the reciprocity method*

Annex A forms an integral part of this part of ISO 5347.

Methods for the calibration of vibration and shock pick-ups —

Part 2:
Primary shock calibration by light cutting

1 Scope

ISO 5347 comprises a series of documents dealing with methods for the calibration of vibration and shock pick-ups.

This part of ISO 5347 lays down detailed specifications for the instrumentation and procedure to be used for primary shock calibration of accelerometers by light cutting. It applies to rectilinear accelerometers of the strain gauge, piezoresistive and piezoelectric types and to primary standards.

This part of ISO 5347 is applicable for a time range from 0,1 m/s to 10 m/s and a dynamic range from 100 m/s^2 to 10^5 m/s^2.

The limits of uncertainty applicable are ± 3 % of the reading.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 5347. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 5347 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 5347-1:1993, *Methods for the calibration of vibration and shock pick-ups — Part 1: Primary vibration calibration by laser interferometry.*

ISO 5347-5:1993, *Methods for the calibration of vibration and shock pick-ups — Part 5: Calibration by Earth's gravitation.*

3 Apparatus

3.1 Equipment capable of maintaining room temperature at 23 °C ± 3 °C.

3.2 Shock machine (see figure 1), with a hammer (a steel ball is recommended) which is permitted to move and to strike an anvil to which the accelerometer is attached. The hammer imparts a motion to the anvil which is permitted to accelerate freely while the hammer is automatically caught up.

Steel springs or cushioning pads of rubber or paper shall be used on top of the anvil to obtain the desired pulse duration.

The shock pulses obtained shall have the shape of a half-sine wave.

The resonance frequencies of the hammer and of the anvil shall be at least 10/T, where T is the pulse duration, in seconds.

In order to avoid influences from resonances in the shock machine structure, the hammer and the anvil shall operate freely from the structure.

The hammer and the anvil shall be aligned with a maximum distance between the two centrelines of ± 0,2 mm.
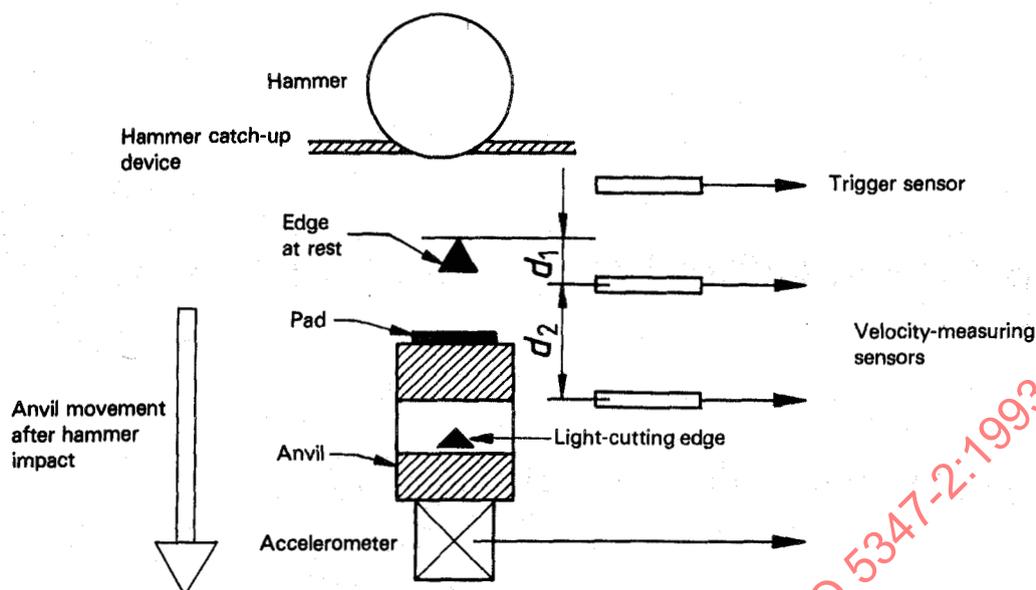
Figure 1 — Shock machine

At rest, the anvil shall be supported in such a way that it can be released at the impact of the hammer with no velocity loss and no asymmetric forces causing rotation, i.e. the support shall act close to the anvil centreline.

The velocity of the anvil after impact shall be measured by two light sensors placed at a known distance apart (25 mm is recommended) measured to a accuracy of $\pm$ 0,05 %. The light-cutting edge shall be placed in a hole through the centre of gravity of the anvil. (It is recommended that a third sensor be used to trigger the shock-measuring equipment.)

By measurements and calculation it shall be shown that the loss of velocity due to anvil rotation is less than 0,2 %.

The distance between the starting point for anvil movement and the first velocity measurement sensor shall be measured with an accuracy better than $\pm$ 1 %.

The shape of the holes, the anvil light-cutting edge and the position of the sensors shall be adjusted so the rise time of the voltage change is of the order of 0,01 ms.

3.3 Time-measuring instrumentation, having the following characteristics:

— measuring range: 10 ms to 0,1 ms,

— uncertainty maximum: $\pm$ 0,01 % of reading.

3.4 Acceleration/time recording equipment.

Memory oscilloscope or transient recorder is recommended.

Built-in circuits for integrating the voltage/time record of pick-up output is recommended. If this is not possible, a strip chart or $X-Y$ recorder shall be used to obtain a readout of the stored transient.

The equipment shall have the following characteristics:

— range: 1 µs to 10 ms and 0 to 50 V;

— uncertainty:

    for time: maximum $\pm$ 2 % of reading;

    for voltage: maximum $\pm$ 1 % of reading;

    for area: maximum $\pm$ 3 % of reading.

— linearity: maximum $\pm$ 1 % deviation from best fit line.

As the recording equipment acts as a low-pass filter, the same requirements specified for the low-pass filters (see 3.5) are valid for this equipment.

The frequency response shall be flat within $\pm$ 3 dB from 0,008/T to 10/T Hz, where T is the pulse duration.

3.5 Low-pass filter.

The use of low-pass filters shall be avoided.

If filters have to be used, the -3 dB lower limiting frequency shall be lower than $0,008/T$ and the -3 dB upper limiting frequency shall be higher than $10/T$, where T is the pulse duration.

NOTE 1 The same requirements are valid for amplifiers and recording equipment.

3.6 Other apparatus requirements.

Accelerometer and accelerometer amplifier shall normally be considered as one unit, and shall be utilised and calibrated together.

The accelerometer shall be structurally rigid. The base strain sensitivity shall be $< 0,2 \times 10^{-8}$ m/s^2 at a base strain of $2,5 \times 10^{-4}$ m/s^2, the transverse sensitivity $< 2\%$ and the stability of the accelerometer/amplifier combination shall be better than $0,2\%$ of the reading per year at reference values. The mounted resonance frequency shall be higher than $20/T$, where T is the pulse duration.

If there are filters in the amplifier, the filter cut-off frequency shall comply with the filter settings specified in 3.5. The frequency response shall be flat within ± 3 dB from $0,008/T$ to $10/T$ Hz, where T is the pulse duration.

4 Preferred pulse durations and accelerations

The following shock pulse durations, in milliseconds, shall be used:

— 0,1; 0,2; 0,5; 1; 2; 5; 10.

The following accelerations, in metres per second squared, shall be used:

— 100; 200; 500;

— 1 000; 2 000; 5 000;

— 10 000; 20 000; 50 000; 100 000.

5 Method

5.1 Test procedure

The hammer function and the velocity measurement system shall be checked by removing the hammer catch-up device and the anvil in order to allow the hammer to pass by the sensors.

Drop the hammer from different heights and measure the velocity.

Calculate the velocity v, in metres per second, from the drop height using the following formula:

$$v = \sqrt{2gh}$$

where

g is the acceleration due to gravity, in metres per second squared, using the local value to four significant figures;

h is the drop height, in metres, the distance between the lower part of the hammer and the upper part of the sensor. Accuracy $\pm 0,1$ mm.

The difference between the measured and the calculated velocities shall be less than $\pm 0,1\%$.

For shock calibrations, the sinusoidal vibration calibration factor according to ISO 5347-1 or ISO 5347-5 shall be used as reference calibration factor.

The shock motion calibrations are then used to measure the amplitude linearity deviations at high accelerations.

By giving the hammer different velocities and using different anvils and different springs or cushion pads, determine the shock calibration factors at the standard selected shock pulse durations and accelerations, and for the standard amplifier range switch positions.

The results shall be given as a percentage deviation from the sinusoidal reference calibration factor, where applicable.

The measured anvil velocity shall be compensated for the velocity change before the first velocity measurement sensor and for the velocity change between the sensors because of acceleration due to gravity.

As the accelerometer output signal is not always a true harmonic, the area under the recorded curve shall be determined by numerical or electrical integration.

5.2 Expression of results

Calculate the shock calibration factor, S_{sh}, expressed in volts per (metre per second squared) [V/(m/s^2)], using the following formula.

$$S_{sh} = \frac{A}{\Delta v}$$

where

A is the area under the recorded curve of the accelerometer output, in volts, against time, in seconds;

Δv is the anvil velocity change, in metres per second, given by the following formula:

$$\Delta v = \sqrt{\left(\frac{d_2}{t} - \frac{t \times g}{2} \right)^2 - 2g \times d_1}$$

in which

d_2 is the distance between the velocity-measuring sensors, in metres;

t is the time between the two sensors, in seconds;

g is the acceleration due to gravity, in metres per second squared (to three significant figures);

d_1 is the distance between the anvil light-cutting edge at rest and the first velocity measuring sensor, in metres.

The acceleration curve shall always be checked directly on an oscilloscope or recorder without filters and amplifiers.

NOTE 2   If there is a zero shift in the signal, the zero point immediately before the shock and the shifted zero point immediately after the shock shall be connected by a straight line, the line being the baseline for acceleration determination.

When the calibration results are reported, the total uncertainty of the calibration and the corresponding confidence level, calculated in accordance with annex A, shall also be reported.

A confidence level of 95 % shall be used.

Annex A
(normative)

Calculation of uncertainty

A.1 Calculation of total uncertainty

The total uncertainty of the calibration for the specified confidence level (for the purpose of this part of ISO 5347, CL = 95 %), X_{95}, shall be calculated from the following formula:

$$X_{95} = \pm \sqrt{X_r^2 + X_s^2}$$

where

X_r is the random uncertainty;

X_s is the systematic uncertainty.

The random uncertainty for the specified confidence level, $X_{r(95)}$, is calculated from the following formula:

$$X_{r(95)} = \pm t \left[\frac{e_{r1}^2 + e_{r2}^2 + e_{r3}^2 + ... + e_{rn}^2}{n(n-1)} \right]^{1/2}$$

where

e_{r1}, e_{r2}, etc.   are the deviations from the arithmetic mean of single measurements in the series;

n is the number of measurements;

t is the value from Student's distribution for the specified confidence level and the number of measurements.

The systematic errors shall, first of all, be eliminated or corrected. The remaining uncertainty, $X_{s(95)}$, shall be taken into account by using the following formula:

$$X_{s(95)} = \frac{K}{\sqrt{3}} \times e_{S,sh}$$

where

K equals 2,0 for the 95 % confidence level;

$e_{S,sh}$ is the absolute uncertainty for the shock calibration factor for the calibrated pulse times, accelerations and amplifier gain settings, expressed in volts per (metre per second squared) (see A.2).

A.2 Calculation of the absolute uncertainty for the shock calibration factor, $e_{S,sh}$, for calibrated pulse times, accelerations and amplifier gain settings

The absolute uncertainty for the shock calibration factor, $e_{S,sh}$, in volts per metre second squared, for the calibrated pulse times, accelerations and amplifier gain settings is calculated by the law of combination of errors from the following formula:

$$\frac{e_{S,sh}}{S_{sh}} = \pm \left[\left(\frac{e_{d_2}}{d_2} \right)^2 + \left(\frac{e_t}{t} \right)^2 + \left(\frac{e_s}{s} \right)^2 + \left(\frac{e_T}{T} \right)^2 + \left(\frac{e_a}{a_{max}} \right)^2 + \left(\frac{L_M}{100} \right)^2 \right]^{1/2}$$

where

S_{sh} is the shock calibration factor (amplitude-dependent), in volts per metre second squared (see 5.2);