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Methods for the calibration of vibration and shock transducers —

Part 22:
Shock calibration by comparison to a reference transducer

AMENDMENT 1

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

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

AMENDEMENT 1

Reference number
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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*.

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Methods for the calibration of vibration and shock transducers —

Part 22: Shock calibration by comparison to a reference transducer

AMENDMENT 1

Page 1, Clause 1

Replace the 2nd sentence of the 1st paragraph by:

The methods are applicable in a shock pulse duration range[1)] of 0,025 ms to 8,0 ms and a dynamic range (peak value) of 100 m/s^2 to 2 000 km/s^2 (time dependent).

Replace NOTE 1 by the following:

NOTE 1 Larger accelerations (peak values) than 100 km/s^2 and shorter pulse durations than 0,05 ms are possible with traceability to ISO 16063-13 under the following conditions for the primary shock calibration.

— The shock machine is based on wave propagation inside a long thin bar as specified in ISO 16063-13:2001, 4.3.

— An interferometer method and procedure specified in ISO 16063-13, 4.6 is used observing the maximum measurable velocity.

— The uncertainty requirements specified in ISO 16063-13 are complied with.

— Reference to primary methodologies (traceability) is limited to the maximum acceleration value used in the primary calibration.

Page 1, Clause 2

Add the following to the Normative references:

ISO 16063-13:2001, *Methods for the calibration of vibration and shock transducers — Part 13: Primary shock calibration using laser interferometry*

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Page 2, Clause 4, Table 1

Replace the table by the following, thereby substituting 2 000 for 100 as the acceleration peak magnitude and changing the corresponding minimum pulse duration.

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	2	5 %
Dropball	100	0,100	5 %
Pneumatically operated piston	100	0,100	5 %
Hopkinson bar with velocity comparison	2 000[c]	0,025[c]	10 %
Hopkinson bar with acceleration comparison	2 000[c]	0,025[c]	6 %
Split Hopkinson bar with force comparison	2 000[c]	0,025[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] In the case of Hopkinson bars, the minimum pulse duration is limited by the bandwidth over which the bar approximates an ideal compressional waveguide as dictated by the diameter and material properties of the bar. For more information, see Annex C.

Page 8, 5.3.1

In the second sentence, substitute “which has” by “with” so that the sentence reads:

This part of ISO 16063 specifies the range from 100 m/s^2 to 2 000 km/s^2, with reference to primary methodologies (see ISO 16063-13 for details).

Page 8, 5.3.2, 2nd sentence

Add the following to the end of the sentence:

in accordance with ISO 16063-13:2001, 4.6.

Page 9, 5.5

In the last sentence, change 10 bits respectively 12 bits to 12 bits respectively 16 bits so that it reads:

A resolution of greater than or equal to 12 bits, preferably 16 bits, is used for measurement of the transducer output.

Page 10, Clause 7, a)

Add 2 000 000 to the series of accelerations so that it reads:

100, 200, 500, 1 000, 2 000, 5 000, 10 000, 20 000, 50 000, 100 000, 200 000, 500 000, 1 000 000, 2 000 000

Page 10, Clause 7, b)

Add 0,025 to the series of shock pulse duration so that it reads:

0,025; 0,05; 0,07; 0,1; 0,2; 0,5; 1; 2; 3; 5; 8

Page 10, Clause 7

Add the following sentence:

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It is recommended that a minimum pulse duration of the shock applied to the unit under test be calculated with the relation $t_{shock} \geq 5/f_{res}$.

Page 14, 8.3.2.3, i)

In the first line, change $u_{S,peak}$ *to* $u_{X,peak}$.

Page 16, A.2

In the heading, change ($S_{h,t}$) *to* ($S_{sh,t}$), *twice.*

In the first paragraph, line 4, change S_{sh} *to* $S_{sh,t}$.

Page 17, Table A.1

In the 8th entry, change $u(R_F)$ *to* $u(R_{MP})$.

In the 9th entry, change $u(R_{VD})$ *to* $u(R_{TEP})$.

Page 20, Table B.2

Replace the heading of the table with the following, thereby substituting 2 000 km/s² for 100 km/s² and 0,025 ms for 0,3 ms in the relative standard uncertainty column.

	Uncertainty component description	**Relative standard uncertainty** % (example value)
	Amplitude range up to Pulse duration range above	2 000 km/s^2 0,025 ms

Page 21, Table B.3

In section B. of the table, "Transducer under test", in the relative standard uncertainty column for entry 2, "Signal conditioner/amplifier", insert an em dash, "—".

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New page 22, Annex C

Insert the following new annex, following Annex B:

Annex C

(informative)

Dispersion in bars

Dispersion in a long slender bar (Kolsky bar, Davies bar, Hopkinson bar etc.) is caused by different frequencies in a shock pulse travelling at different wave speeds. This occurs where the ratio between c [the wave speed for a particular wavelength (frequency)] and c_0 [the nominal wave speed for infinitely long waves in the bar (based on material properties)] is less than 1,0 or

$$\frac{c}{c_0} < 1,0 \tag{C.1}$$

Dispersion appears as apparent frequency content on the time history measurement of the shock pulse; however, a discrete Fourier transform will not show the frequency that appears in the time history. The apparent frequency content is caused by the phase difference between the frequency components in the shock pulse. This phenomenon has been well known for centuries and is documented in several classical references.[5] [6] Figure C.1 shows the ratio of wave speed (also known as *phase velocity*) to the nominal wave speed (wave speed for an infinite wavelength) as a function of the ratio of the radius, a, of a bar to wavelength, λ, for the first root of the "frequency equation".[5] [6]

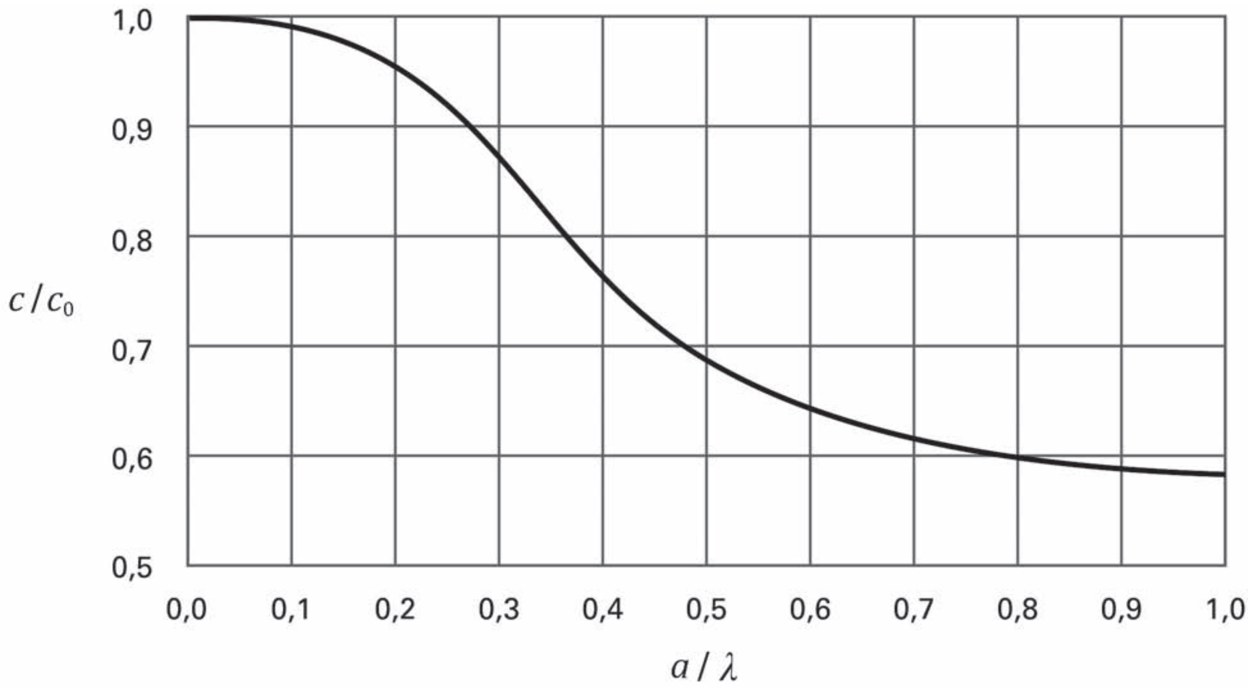

Figure C.1 — Ratio of wave speed to nominal wave speed as a function of bar radius to wavelength for a Poisson's ratio of 0,29

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The requirement for a one-dimensional wave is the value for Formula (C.1)[6] and in Figure C.1 of 0,99 or 1 % dispersion. The corresponding value of the abscissa in Figure 1 is:

$$\frac{a}{\lambda} < 0{,}1 \tag{C.2}$$

where

a is the bar radius;

λ is the wavelength.

The value in Formula (C.2) yields a wavelength that is long enough to approximate its non-dispersive or infinite value with a ratio of phase velocity to velocity of 0,99 or more.[6]

Therefore, the requirement for a one-dimensional wave with wavelength, λ, to propagate in a bar with constant cross section without attenuation or distortion and 1 % dispersion is:[5] [6]

$$\lambda > 10\,a \tag{C.3}$$

Formula (C.3) also implies a minimum length of the bar so that the wavelength appears infinite, and in general, the longer the bar, the more uniform the stress (strain, force, or velocity) wave in a bar cross section. For practical reasons, bars with a length of 200a are generally used. Since

$$\lambda = \frac{c}{f} \approx \frac{c_0}{f} \tag{C.4}$$

where f is the effective bandwidth of the shock pulse or the reciprocal of the duration of the pulse, T_{min}, the final expression is

$$T_{\text{min}} = \frac{10a}{c_0} \tag{C.5}$$

So, for a diameter of a bar of 19,1 mm and materials of steel, titanium, or aluminium, the minimum duration is 18,8 µs. If a larger radius bar is used, the minimum duration will increase as shown by Formula (C.5). This formula applies for shock pulses (haversine, for example) with relatively long rise and fall times where these times are approximately half the pulse duration, where duration is defined as the reciprocal of the effective bandwidth in the shock pulse. For shock pulses with very fast rise times (such as square waves, for example), the duration of the rise time (the time between 10 % and 90 % of the maximum value) is defined as the reciprocal of the effective bandwidth in the shock pulse.

Page 23, Bibliography, entry 21

Delete ISO 16063-13:2001.

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