INTERNATIONAL STANDARD

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Second edition
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Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity

Vibrations mécaniques des machines tournantes ou alternatives — Exigences relatives aux appareils de mesure de l'intensité vibratoire

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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 2954 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

This second edition cancels and replaces the first edition (ISO 2954:1975), which has been technically revised.

The main changes are:

— Filters defined as standardized third-order Butterworth filters.

— The standard now covers other frequency ranges than 10 Hz to 1 000 Hz.

Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity

1 Scope

This International Standard specifies requirements which it is necessary for a measuring instrument for vibration severity of machines to meet if inaccuracies of measurement made on the casing of machines, particularly when making repeated measurements for trend monitoring of a certain machine, are not to exceed a specific value.

The instruments covered by this International Standard give direct indication or recording of root-mean-square (r.m.s.) vibration velocity that is defined as a measurement unit.

NOTE 1 A method of checking true r.m.s. indication is described in Annex A. This method is mainly retained for instruments not based on modern analogue to digital conversion and numerical calculation of r.m.s., but can also be applied to instruments which are so based.

NOTE 2 Subject to adaptation of the measurement frequency range, these instruments can be used for other applications where similar accuracy of measurement is required, measurement of vibration velocity of structures, tunnels, bridges, etc. Optionally phase measurements may be included.

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 undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO 10816-1:1995, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 1: General guidelines*

ISO 10816-6:1995, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 6: Reciprocating machines with power ratings above 100 kW*

3 Terms and definitions

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

4 Measurement quantities

The measurement quantities given in Table 1 are used to describe mechanical vibration of non-rotating parts.

Integration and differentiation among the measurement quantities is allowed both for broad band and discrete frequency component signals (see ISO 10816-1:1995, Annex A).

The maximum measured vibration magnitude is called vibration severity. It can be given a severity grade (see e.g. ISO 10816-6:1995, Table 1).

NOTE Formerly, vibration severity was normally only meant to be the maximum broad-band r.m.s. vibration velocity from 10 Hz to 1 000 Hz. This International Standard specifies the requirements for such a limited instrument, but also permits use of other frequency ranges.

The instrument should preferably be capable of measuring the measurement quantities given in Table 1, but shall at least measure r.m.s. vibration velocity over the frequency range defined in 5.3.

If values at discrete frequencies are filtered from broad-band measurements, the band-pass filter shall have a suitable bandwidth. Phase relative to a shaft trigger reference or similar source may also be measured to give the vibration vector with its magnitude as amplitude or as r.m.s. value.

The actual measurement quantity shall be displayed and/or output as an analogue voltage signal or as digital data. The instrument manufacturer shall give details of the interface(s), which should comply with common standards.

Table 1 — Measurement quantities for non-rotating parts

Measurement quantity	Unit[a]	Broad-band value[b]	At discrete frequencies[c]	
Displacement[d]	µm	r.m.s.	—	peak to peak amplitude
Vibration velocity[e]	mm/s	r.m.s.	peak amplitude	—
Acceleration[f]	m/s^2	r.m.s.[g]	peak amplitude	—

[a] Other units like inches, in/s and g_n are commonly used in some parts of the world and can be accepted, but the SI system should preferably be used.

[b] Over a defined frequency range (see 5.3).

[c] Directly measured or filtered from broad-band measurements with a band-pass filter. Phase may also be measured to give the vibration vector if a second channel and a reference signal are available.

[d] Especially for low-speed range.

[e] As a general measurement quantity.

[f] Especially for high-speed range and for rolling element bearings. See ISO 10816-1:1995, Figure 6 or ISO 10816-6:1995, Annex C.

[g] For measurements on rolling element bearings, maximum magnitude is also common.

5 General requirements

5.1 A vibration measuring instrument usually consists of: a vibration transducer; an indicating unit; and a power supply system.

5.2 The requirements specified in this clause apply to the general characteristics of the complete assembly of the transducer and the indicating unit. Clauses 6 and 7 contain the detailed requirements for each of these main units.

5.3 The measurement frequency range of the vibration severity measuring instrument shall be from 10 Hz to 1 000 Hz but can include other ranges. (In some parts of ISO 10816[2] a lower cut-off frequency of 2 Hz or even less is used. The requirements to the frequency response can be found from the formulas in 5.4).

5.4 The sensitivity within the measurement frequency range shall not deviate from the reference sensitivity at the reference frequency by more than the quantities given in Table 2 and shown graphically in Figures 1 and 2 for a reference frequency of 79,4 Hz.

NOTE The reference frequency may also be 1 000 rad/s, i.e. approximately 160 Hz.

The band-limiting element is a combination of high- and low-pass third-order Butterworth filter characteristics. These components are defined as follows:

a) high pass

$$H_{\mathrm{h}}(s) = 1\Big/\left[1+\frac{\omega_1}{Q_1 s}+\left(\frac{\omega_1}{Q_2 s}\right)^2+\left(\frac{\omega_1}{s}\right)^3\right] \qquad (1)$$

b) low pass

$$H_l(s) = 1\Big/\left[1+\frac{s}{Q_3\omega_2}+\left(\frac{s}{Q_4\omega_2}\right)^2+\left(\frac{s}{\omega_2}\right)^3\right] \quad (2)$$

The product $H_h(s)\,H_l(s)$ represents the band-limiting transfer function.

Table 2 — Sensitivity relative to the reference sensitivity and limiting values of the permissible deviation within the frequency interval from 1 Hz to 10 000 Hz for an instrument with a nominal frequency range from 10 Hz to 1 000 Hz

Frequency Hz	Nominal sensitivity dB	Upper tolerance bands dB	Lower tolerance bands dB	Tolerance dB	Nominal values	Upper tolerance bands	Lower tolerance bands
1	−60,0	−40,0	−80,0	±20	0,001	0,010 0	0,000 1
1,26	−54,0	−38,0	−70,0	±16	0,002 0	0,012 6	0,000 3
1,58	−48,0	−36,0	−60,0	±12	0,004 0	0,015 8	0,001 0
2,00	−42,0	−34,0	−50,0	±8	0,007 9	0,020 0	0,003 2
2,51	−36,0	−32,0	−40,0	±4	0,015 8	0,025 1	0,010 0
3,16	−30,0	−26,0	−34,0	±4	0,031 6	0,050 1	0,019 9
3,98	−24,0	−20,0	−28,0	±4	0,063	0,100	0,040
5,01	−18,1	−16,1	−20,1	±2	0,125	0,157	0,099
6,31	−12,3	−10,3	−14,3	±2	0,244	0,307	0,194
7,94	−7,0	−5,0	−9,0	±2	0,448	0,564	0,356
10	−3,01	−1,01	-5,01	±2	0,707	0,890	0,562
12,6	-0,97	-0,14	−1,89	+0,83 −0,92	0,894	0,984	0,804
15,8	−0,27	0,56	−1,19	+0,83 −0,92	0,970	1,067	0,872
20,0	−0,07	0,76	−0,99	+0,83 −0,92	0,992	1,092	0,892
25,1	−0,02	0,81	−0,94	+0,83 −0,92	0,998	1,098	0,898
31,6	0,00	0,83	−0,92	+0,83 −0,92	1,000	1,100	0,900
39,8	0,00	0,83	−0,92	+0,83 −0,92	1,000	1,100	0,900
50,1	0,00	0,83	−0,92	+0,83 −0,92	1,000	1,100	0,900
63,1	0,00	0,83	−0,92	+0,83 −0,92	1,000	1,100	0,900
79,4	0,00	0,00	0,00	+0,83 −0,92	1,000	1,000	1,000
100	0,00	0,83	−0,92	+0,83 −0,92	1,000	1,100	0,900

NOTE 1 The frequencies used are the theoretical base-10 one-third octave frequencies as defined in IEC 61260.[8] The nominal frequencies found in ISO 266[1] can also be used because the differences are very small.

NOTE 2 The limits in the pass-band are maintained from ISO 2954:1975 to be 10 % limits, here expressed in decibels. The tolerances at the corner frequencies have been made to follow the theoretical curve for the filter rather than trying to maintain the precise tolerances in ISO 2954:1975.

Table 2 *(continued)*

Frequency Hz	Nominal sensitivity dB	Upper tolerance bands dB	Lower tolerance bands dB	Tolerance dB	Nominal values	Upper tolerance bands	Lower tolerance bands
126	0,00	0,83	−0,92	+0,83 −0,92	1,000	1,100	0,900
158	0,00	0,83	−0,92	+0,83 −0,92	1,000	1,100	0,900
200	0,00	0,83	−0,92	+0,83 −0,92	1,000	1,100	0,900
251	0,00	0,83	−0,92	+0,83 −0,92	1,000	1,100	0,900
316	0,00	0,83	−0,92	+0,83 −0,92	1,000	1,100	0,900
398	−0,02	0,81	−0,94	+0,83 −0,92	0,998	1,098	0,898
501	−0,07	0,76	−0,99	+0,83 −0,92	0,992	1,092	0,892
631	−0,27	0,56	−1,19	+0,83 −0,92	0,970	1,067	0,872
794	−0,97	−0,14	−1,89	+0,83 −0,92	0,894	0,984	0,804
1 000	−3,01	−1,01	−5,01	±2	0,707	0,890	0,562
1 259	−7,0	−5,0	−9,0	±2	0,448	0,564	0,356
1 585	−12,3	−10,3	−14,3	±2	0,244	0,307	0,194
1 995	−18,1	−16,1	−20,1	±2	0,125	0,157	0,099
2 512	−24,0	−20,0	−28,0	±4	0,063	0,100	0,040
3 162	−30,0	−26,0	−34,0	±4	0,031 6	0,050 1	0,019 9
3 981	−36,0	−32,0	−40,0	±4	0,015 8	0,025 1	0,010 0
5 012	−42,0	−34,0	−50,0	± 8	0,007 9	0,020 0	0,003 2
6 310	−48,0	−36,0	−60,0	± 12	0,004 0	0,015 8	0,001 0
7 943	−54,0	−38,0	−70,0	± 16	0,002 0	0,012 6	0,000 3
10 000	−60,0	−40,0	−80,0	± 20	0,001	0,010 0	0,000 1

NOTE 1 The frequencies used are the theoretical base-10 one-third octave frequencies as defined in IEC 61260.[8] The nominal frequencies found in ISO 266[1] can also be used because the differences are very small.

NOTE 2 The limits in the pass-band are maintained from ISO 2954:1975 to be 10 % limits, here expressed in decibels. The tolerances at the corner frequencies have been made to follow the theoretical curve for the filter rather than trying to maintain the precise tolerances in ISO 2954:1975.

The most common interpretation of these equations is in the frequency domain, where they describe the modulus (magnitude) and phase of the band limitation as functions of the imaginary angular frequency:

$$s = \mathrm{j}2\pi f = \mathrm{j}\omega \tag{3}$$

where

ω is the angular frequency, in radians per second;

f is the frequency, in hertz.

NOTE 1 Sometimes the symbol p is used instead of s.

NOTE 2 It is possible to interpret s as the variable of the Laplace transform.

The magnitudes of the filter responses are then given by:

— high pass

$$\left|H_{\mathrm{h}}(\mathrm{j}\omega)\right| = \frac{1}{\sqrt{1+(\omega_1/\omega)^6}} \tag{4}$$

— low pass

$$\left|H_{\mathrm{l}}(\mathrm{j}\omega)\right| = \frac{1}{\sqrt{1+(\omega/\omega_2)^6}} \tag{5}$$

— band pass

$$\left|H(\mathrm{j}\omega)\right| = \frac{1}{\sqrt{1+(\omega_1/\omega)^6}}\,\frac{1}{\sqrt{1+(\omega/\omega_2)^6}} \tag{6}$$

See the penultimate paragraph and 5.3, where f_1 may be any suitable lower cut-off frequency and f_2 may be any suitable upper cut-off frequency.

The parameters for the measurement frequency range 10 Hz to 1 000 Hz are:

f_1 = 10 Hz $Q_1 = Q_3 = 1/2$

f_2 = 1 000 Hz $Q_2 = Q_4 = 1/\sqrt{2}$

To minimize measurement errors caused by the interference due to vibrations with frequencies outside the measurement frequency range, the sensitivity shall decrease rapidly in a clearly defined manner at the limits of the measurement frequency range. Both the required nominal values of the sensitivity and the permissible minimum and maximum values are given in Table 2.

To preclude doubts about the course of the sensitivity between the cut-off frequencies shown in Table 2, Figures 1 and 2 illustrate the course of the nominal value of the relative sensitivity and the limit of the permissible deviation within the whole frequency range from 1 Hz to 10 000 Hz.

If the total is found, e.g. by using narrow band filtering, all contributions within the frequency range 1 Hz to 10 000 Hz shall be summed.

In some cases, it may be necessary to limit or expand further the measurement frequency range at its upper or lower boundaries to avoid interfering vibrations that are irrelevant to the assessment of the vibration characteristics of a machine or to include important frequencies. For this purpose, the instrument may be equipped with additional or modified high-pass or low-pass filters. It is recommended that the cut-off frequencies, f_1 and f_2, of these filters be selected in accordance with IEC 61260[8] one-third octave specifications in the range 1 Hz to 10 000 Hz and the edge steepness kept as the filters specified in this International Standard.

Vibration severity can be measured in accordance with the various parts of ISO 10816[2] by changing filter parameters. To avoid errors, it is necessary to state the 3 dB cut-off frequencies for the measurement frequency range as well as the measured value, e.g. v_{rms} (2 Hz to 1 000 Hz) = 7,5 mm/s.