BS ISO 15242-1:2015

BSI Standards Publication

Rolling bearings — Measuring methods for vibration

Part 1: Fundamentals

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National foreword

This British Standard is the UK implementation of ISO 15242-1:2015. It supersedes BS ISO 15242-1:2004 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee MCE/7, Rolling bearings.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Part 1: **Fundamentals**

Roulements — Méthodes de mesurage des vibrations —

Partie 1: Principes fondamentaux

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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.

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 4, *Rolling bearings*.

This second edition cancels and replaces the first edition (ISO 15242-1:2004), which has been technically revised.

ISO 15242 consists of the following parts, under the general title *Rolling bearings — Measuring methods for vibration*:

— *Part 1: Fundamentals*

— *Part 2: Radial ball bearings with cylindrical bore and outside surface*

— *Part 3: Radial spherical and tapered roller bearings with cylindrical bore and outside surface*

— *Part 4: Radial cylindrical roller bearings with cylindrical bore and outside surface*

Introduction

Vibration in rotating rolling bearings can be of importance as an operating characteristic of such bearings. The vibration can affect the performance of the mechanical system incorporating the bearing and can result in audible noise when the vibration is transmitted to the environment in which the mechanical system operates, can lead to damages, and can even create health problems.

Vibration of rotating rolling bearings is a complex physical phenomenon dependent on the conditions of operation. Measuring the vibration of an individual bearing under a certain set of conditions does not necessarily characterize the vibration under a different set of conditions or when the bearing becomes part of a larger assembly. Assessment of the audible sound generated by the mechanical system incorporating the bearing is further complicated by the influence of the interface conditions, the location and orientation of the sensing device, and the acoustical environment in which the system operates. Assessment of airborne noise, which for the purpose of this part of ISO 15242 can be defined as any disagreeable and undesired sound, is further complicated by the subjective nature of the terms *disagreeable* and *undesired*. Structure-borne vibration can be considered the driving mechanism that ultimately results in the generation of airborne noise. Only selected methods for the measurement of the structure-borne vibration of rotating rolling bearings are addressed in the current edition of ISO 15242.

This part of ISO 15242 serves to define and specify the physical quantities measured and the general measurement conditions and environment utilized in the measurement of vibration generated by rolling bearings on a measuring device. Based on this part of ISO 15242, parties to the acceptance inspection of rolling bearings may, by agreement, establish acceptance criteria with which to control bearing vibration.

Vibration of rotating rolling bearings can be assessed by a number of means using various types of transducers and measurement conditions. No simple set of values characterizing the vibration of a bearing is adequate for the evaluation of the vibratory performance in all possible applications. Ultimately, a knowledge of the type of bearing, its application and the purpose of the vibration measuring (e.g. as a manufacturing process diagnostic or an assessment of product quality) is required to select the most suitable method for measuring. The field of application for standards on bearing vibration is therefore not universal. However, certain methods have established a wide enough level of application to be considered as standard methods.

This part of ISO 15242 serves to define the general principles involved in vibration measurement. It is intended that further parts will specify, in more detail, the methods for assessing vibration of different types of bearings with cylindrical bore and outside surface.

Rolling bearings — Measuring methods for vibration —

Part 1:
Fundamentals

1 Scope

This part of ISO 15242 specifies measuring methods for vibration of rotating rolling bearings under established measuring conditions, together with calibration of the related measuring systems.

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 286-2, *Geometrical product specifications (GPS) — ISO code system for tolerances on linear sizes — Part 2: Tables of standard tolerance classes and limit deviations for holes and shafts*

ISO 2041:2009, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 5593, *Rolling bearings — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 5593 and the following apply.

3.1
error motion
undesired radial or axial (translational) motion or tilt (angular) motion of an axis of rotation, excluding motions due to changes of temperature or externally applied load

3.2
vibration
mechanical oscillations about an equilibrium point

Note 1 to entry: The oscillations may be periodic or random.

[SOURCE: ISO 2041:2009, 2.1, modified]

3.3
transducer
device designed to convert energy from one form to another in such a manner that the desired characteristics of the input energy appear at the output

Note 1 to entry: The output is usually electrical.

Note 2 to entry: The use of the term “pick-up” is deprecated.

Note 3 to entry: Examples of types of transducers used in vibration measurement are the following:

a) piezoelectric accelerometer;

b) piezoresistive accelerometer;

c) strain-gauge type accelerometer;

d) variable-resistance transducer;

e) electrostatic (capacitor/condenser) transducer;

f) bonded-wire (foil) strain-gauge;

g) variable-reluctance transducer;

h) magnetostriction transducer;

i) moving-conductor transducer;

j) moving-coil transducer;

k) induction transducer;

l) laser vibrometer.

Note 4 to entry: Other types of transducers such as dynamic force transducers may be used, provided their signal can be converted to displacement, velocity or acceleration.

[SOURCE: ISO 2041:2009, 4.1, modified — Note 3 to entry and Note 4 to entry have been added.]

3.4
filter
wave filter
analogue or digital device for separating oscillations on the basis of their frequency, introducing relatively small attenuation to wave oscillations in one or more frequency bands and relatively large attenuation to oscillations of other frequencies

3.5
band-pass filter
filter (3.4) which has a single transmission band extending from a lower cut-off frequency greater than zero to a finite upper cut-off frequency

3.6
nominal upper and lower cut-off frequencies
cut-off frequency
f_{upp} **and** f_{low}
nominal frequencies that define the *band-pass filter* (3.5)

3.7
root mean square velocity
rms velocity
$v_{rms}(t)$
square root of the average of squared values of the vibration velocity within a time interval, T

Note 1 to entry: Root mean square value can also be used for displacement and acceleration.

Note 2 to entry: In the first edition of this part of ISO 15242, root mean square was abbreviated as r.m.s.

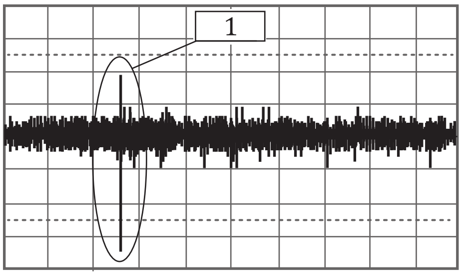
3.8
fundamental period
period
smallest increment of time for which a periodic function repeats itself

Note 1 to entry: If no ambiguity is likely, the fundamental period is called the period.

[SOURCE: ISO 2041:2009, 2.32]

3.9
spike
single significant rapid transient changes in amplitude above the general signal level

Note 1 to entry: Figure 1 shows an example for a spike.



Key

1 spike

Figure 1 — Example showing a spike phenomenon in the time domain

3.10
pulse
significant repetitive rapid transient changes in amplitude above the general signal level

Note 1 to entry: Figure 2 shows an example for a pulse.

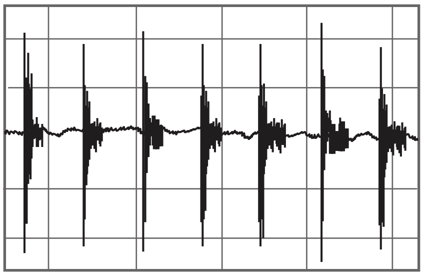


Figure 2 — Example showing a pulse phenomenon in the time domain

4 Fundamental concepts

4.1 Bearing vibration measurement

The diagram in Figure 3 shows the fundamental elements of bearing vibration measurement and the factors that influence the measurement. The numbers in Figure 3 correspond to subclauses of this part of ISO 15242.

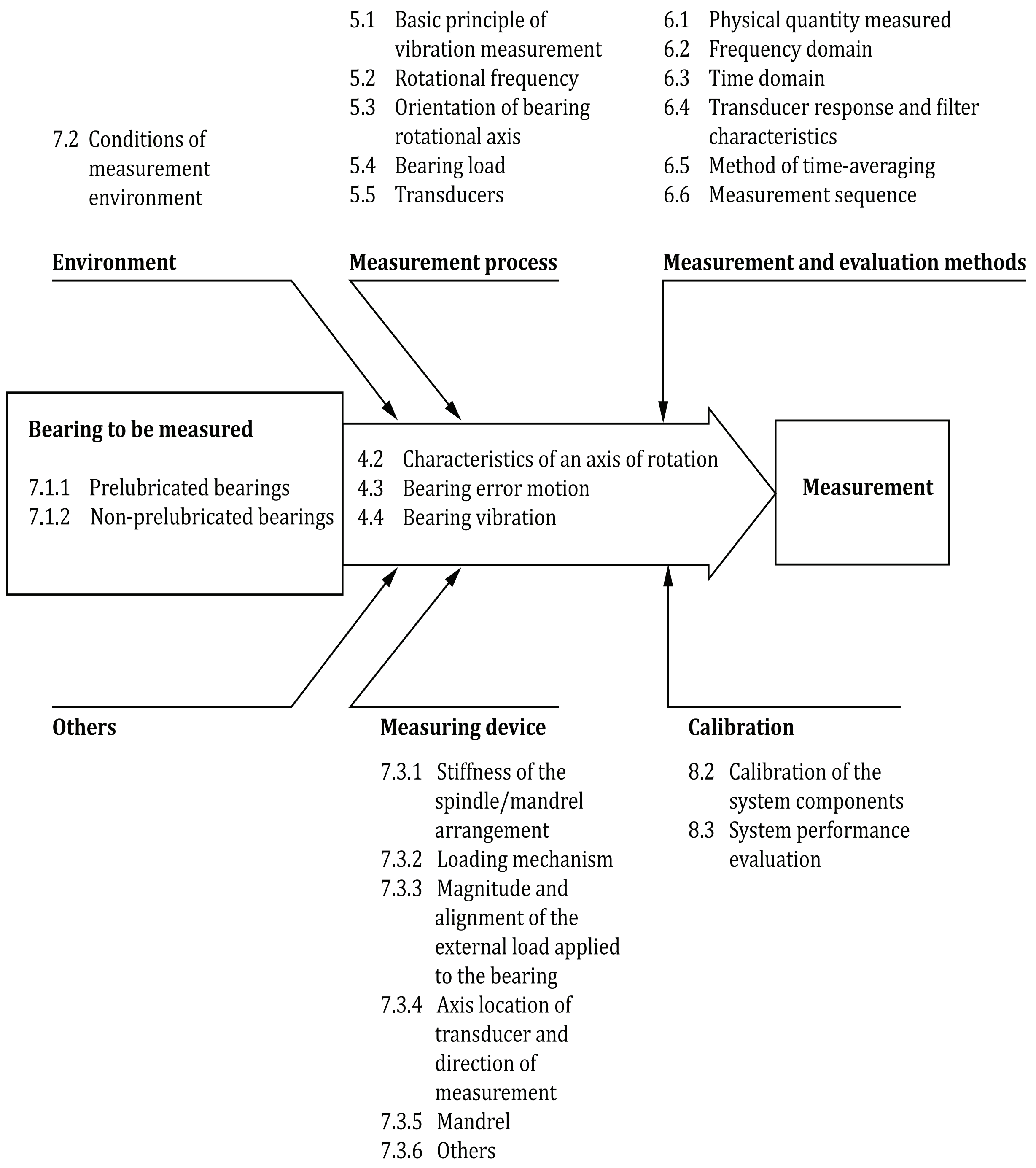


Figure 3 — Fundamental elements of bearing vibration measurement

4.2 Characteristics of an axis of rotation

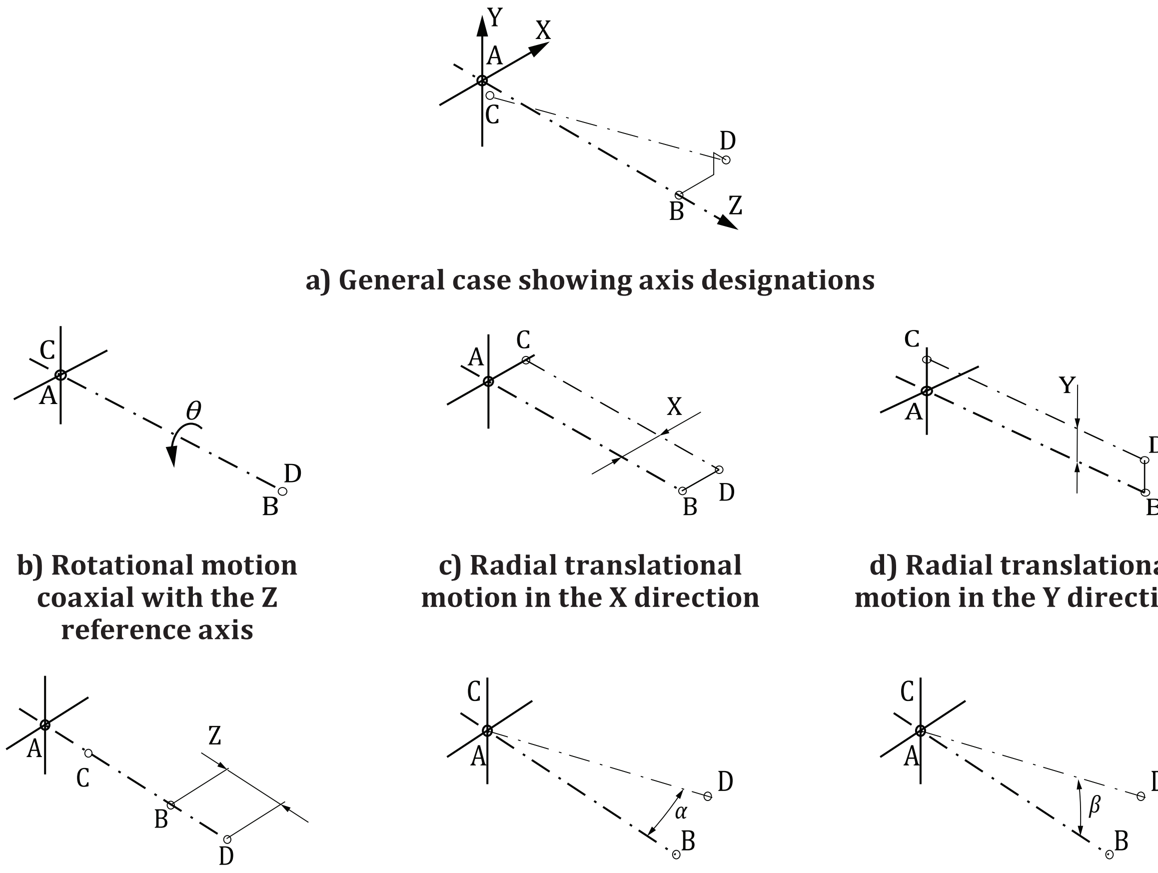
A rotating rolling bearing is designed to provide an axis of rotation for rotational motion of one machine element relative to another while supporting radial and/or axial loads. An axis of rotation may exhibit motion in six basic degrees of freedom. These are shown in Figure 4, and are listed below:

— rotational motion, see Figure 4 b);

— translational motion in a radial direction, i.e. in one or both orthogonal planes passing through the axis of rotation, see Figures 4 c) and 4 d);

— translational motion in an axial direction, i.e. in a direction parallel to the axis of rotation, see Figure 4 e);

— tilt motion in an angular direction, i.e. in one or both orthogonal planes passing through the axis of rotation, see Figures 4 f) and 4 g).



a) General case showing axis designations

b) Rotational motion coaxial with the Z reference axis

c) Radial translational motion in the X direction

d) Radial translational motion in the Y direction

e) Axial translational motion in the Z direction

f) Tilt motion in the X direction with the origin at A

g) Tilt motion in the Y direction with the origin at A

Key

AB Z reference axis

CD axis of rotation

Figure 4 — Schematic diagrams of the six degrees of freedom of an axis of rotation

A rotating rolling bearing will, ideally, have no resistance to externally applied forces in the rotational direction, i.e. zero frictional torque. Depending on the type of external loading the bearing is designed to support, the bearing will exhibit stiffness in any or all of the five remaining degrees of freedom. For example, a bearing with self-aligning capabilities may support radial and axial loading, but will, ideally, exhibit no stiffness in the two tilt directions. Other bearings may be designed to allow free axial motion while exhibiting radial and tilt stiffness.

4.3 Bearing error motion

Displacement of the axis of rotation of a rotating bearing in any of the five non-rotational degrees of freedom for which the bearing is designed to support load is known as bearing error motion. This includes any displacements associated with rotation of the bearing, but excludes displacements due to thermal drift or changes in externally applied load. Error motion is reported in terms of displacement and characterizes the deviation from perfection of an axis of rotation. In a rotating rolling bearing, error motion is a consequence of geometric imperfections of the various internal bearing surfaces that undergo relative motion as the bearing rotates. These geometric imperfections may be an intrinsic characteristic of the bearing components (such as form errors in a manufactured surface) or may be the consequence of distortions of the bearing components introduced during mounting or installation.

4.4 Bearing vibration

The same factors that result in bearing error motion will also result in dynamic vibration of the bearing elements. Vibration is a consequence of the displacements induced by error motion, but with the additional consideration of acceleration-dependent inertial effects and bearing/mounting stiffness characteristics, which will generate internal forces in the bearing. Internal forces will also generate time-variable deformations of the bearing parts, several types of non-intended motions of the rolling elements and cages, and periodic displacements of the cage with respect to the rolling elements or rings. Vibration is generated by error motion under specific circumstances, such as rotational frequency and applied load. Bearing vibration can affect the performance of a mechanical system and can contribute to airborne and structure borne noise of the system that incorporates the bearing.

5 Measurement process

5.1 Basic principle of vibration measurement

For the purposes of this part of ISO 15242, the structure-borne vibration of a rotating rolling bearing is evaluated by mounting a transducer (e.g. displacement, velocity, acceleration or force) at a specified point on one of the bearing rings or on a mechanical element of the test rig that is mechanically coupled to one of the bearing rings. The line of action of the transducer (e.g. axial or radial) shall be specified with respect to a reference system. The bearing is rotated at a fixed rotational frequency under specified loading conditions and the transducer signal is monitored for a specified period of time. The data thus collected are then analysed to calculate one or more parameters that are used to characterize the vibration. These observations yield data on the vibration of the bearing for the selected measurement conditions.

NOTE The results do not necessarily allow conclusions regarding vibration and noise under different operating conditions.

The measurement process can be represented schematically as a combination of the elements as shown in Figure 3. The numbers indicate subclauses of this part of ISO 15242, which provide details on each of these elements of the measurement process.

5.2 Rotational frequency

Bearings vibration shall be measured with the outer ring being stationary and with the inner ring turning at a constant rotational frequency dependent on the size and construction of the bearing (see type-specific parts of ISO 15242). Alternatively, bearings may be measured with a stationary inner ring and a rotating outer ring. The stationary ring is permitted to have small rotational movement during the measurement.

During the measurement, the actual rotational frequency shall not exceed the nominal rotational frequency by more than 1 % and shall not fall below it by more than 2 %.

5.3 Orientation of bearing rotational axis

Bearings vibration may be measured with the axis of rotation vertical or horizontal. With the axis horizontal, the change in orientation of the earth's gravity with respect to the rotating rolling elements can lead to additional vibration unless the centrifugal or induced contact forces on the rolling elements are much greater than their weights.

5.4 Bearing load

In order to achieve well-defined kinematic conditions, bearings shall be loaded during the vibration measurement. Applied loads shall be sufficient to prevent slipping of the rolling elements relative to the inner and outer ring raceways and without affecting the measurement.

5.5 Transducers

The quantity measured is the radial or axial vibration of the measured ring. A transducer converts the mechanical movement to an electrical signal in units of displacement, velocity or acceleration.

When a contact type transducer is used, care shall be taken to ensure that the transducer does not influence the vibrations of the measured ring. Conversely, the contact needs to be sufficiently firm so that all vibrations within the appropriate frequency range are detected. To achieve this, moving masses shall be as low as possible. If vibrations are transferred via a transducer tip that touches the measured ring, the occurrence of contact resonance has to be taken into consideration (see Annex A).

Signals should be presented as velocity as it provides the best resolution over a wide frequency range. The vibrational motion of the measured ring is a complicated superposition of displacements of various amplitudes at different frequencies. Whereas there may be high single amplitudes even at higher frequencies (especially for defective bearings), in general, amplitudes decrease with increasing frequency and decline to nanometre magnitude at a few kilohertz. Because the acoustic pressure is proportional to the velocity signal on the surface, velocity sensors are preferred. The selected transducer shall provide adequate frequency response.

NOTE The correlation of displacement, velocity and acceleration at various frequencies is given in Annex B.

6 Measurement and evaluation methods

6.1 Physical quantity measured

The default physical quantity to be measured is root mean square vibration velocity, v_{rms} (µm/s). The measurement direction is to be radial or axial depending on the bearing type.

6.2 Frequency domain

The velocity signal is to be analysed in one or more frequency bands. The range of the frequency bands depend on the rotational frequency of the spindle. For a rotational frequency of 30 s^{-1} (1 800 min^{-1}), the range of the frequency bands is from 50 Hz to 10 000 Hz. Specific frequency ranges are specified in other parts of ISO 15242.

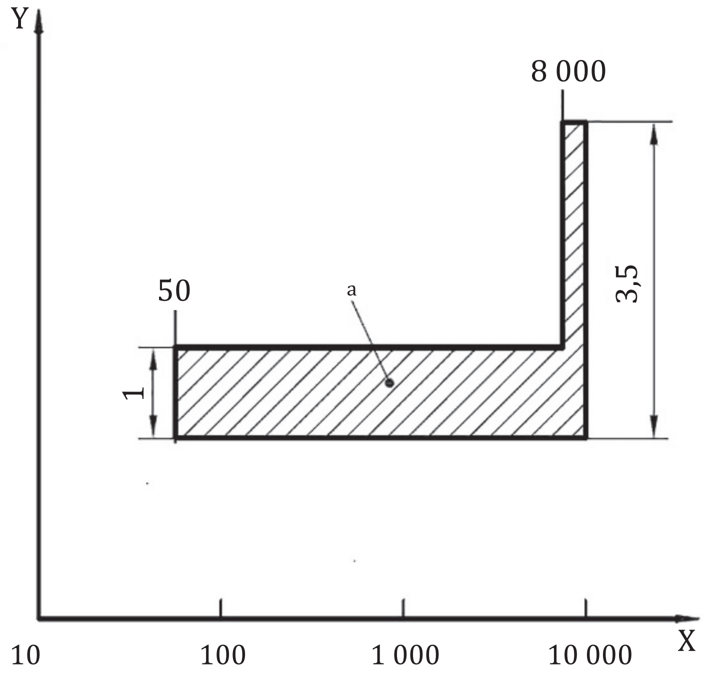
Narrow band spectral analysis of the vibration signal may be considered as a supplementary option.

6.3 Time domain

Detection of pulses or spikes in the time domain velocity signal, usually due to surface defects and/or contamination in the measured bearing, may be considered as a supplementary option. Various evaluation methods exist.

6.4 Transducer response and filter characteristics

Frequency response of the transducer shall fall within the limits specified in Figure 5.



Key

X frequency, Hz

Y output signal/vibration velocity, dB

a Maximum permissible zone.

NOTE For measurements done at ranges different from default (50 Hz to 10 000 Hz), the maximum permissible zone should be adjusted accordingly. For instance, if measured at 3 600 min^{-1}, the zone should be extended up to 20 000 Hz and for lower rotational frequencies, the lower range should be extended accordingly.

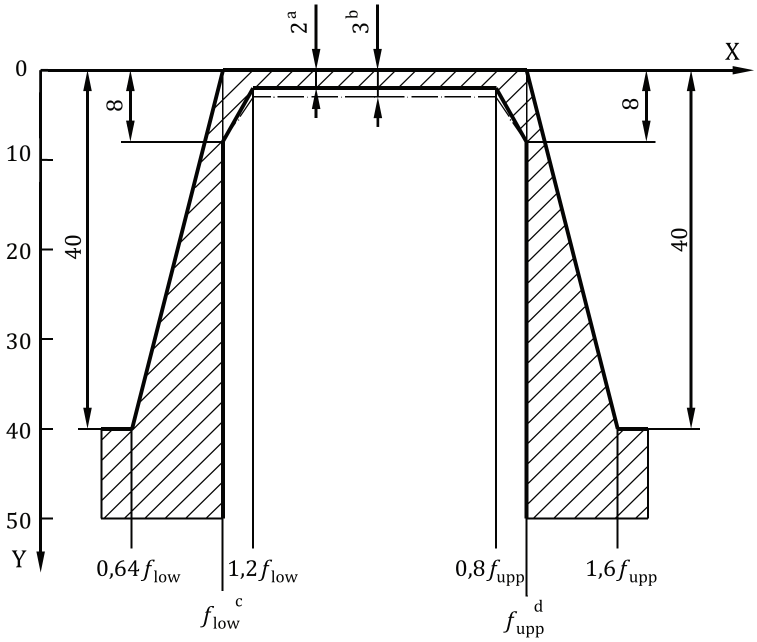
Figure 5 — Transducer response specification

The minimum response requirement of the transducer in Figure 5 shall include the compensated output signal of the amplifier.

Amplitude linearity: The maximum deviation from linearity shall be less than 10 % for vibration amplitudes in the velocity range between 10 µm/s and 3 000 µm/s over the whole frequency range.

The sensitivity of the transducer, as matched with its signal conditioning, shall be specified within ±5 %.

The filter characteristics of the signal conditioning shall fall within the band-pass filter limits specified in Figure 6. The attenuation at all frequencies lower than 64 % of the lower cut-off frequency (f_{low}) and all frequencies greater than 160 % of the upper cut-off frequency (f_{upp}) shall not be less than 40 dB.



Key

X frequency, Hz

Y attenuation, dB

a Recommended range.

b Maximum permissible range.

c Nominal lower cut-off frequency.

d Nominal upper cut-off frequency.

Figure 6 — Filter specification

6.5 Method of time-averaging

The measurement of the velocity signal in each frequency band shall represent a time-average reading over a period of not less than 0,5 s at 1 800 min^{-1} once the readings of the vibration have stabilized, characterized by only an occasional random fluctuation about the average.

The minimum time-averaging period is inverse proportional to the rotational frequency of the spindle.

The accuracy of the root mean square detector shall be within ±5 % of the reading for signals with a crest factor up to five.

6.6 Measurement sequence

Measurements shall be taken at the required number of positions. Details for specific bearing types are given in other parts of ISO 15242.

For acceptance of the bearing, the highest vibration reading for the appropriate frequency range shall be within the limits mutually agreed between the manufacturer and the customer.

7 Conditions for measurement

7.1 Bearing conditions for measurement

7.1.1 Prelubricated bearings

Prelubricated (greased, oiled or solid lubricated) bearings, including sealed and shielded types, shall be measured in the as-delivered condition.

7.1.2 Non-prelubricated bearings

Since contamination affects vibration, the bearings should be effectively cleaned, taking care not to introduce contamination or other sources of vibration.

NOTE Some preservatives meet the lubrication requirements for vibration measuring. In this case, it is not necessary to remove the preservative.

Non-prelubricated bearings shall be adequately lubricated with fine filtered oil, typically having a viscosity in the range of 10 mm^2/s to 100 mm^2/s, appropriate to bearing type and size.

The lubrication procedure shall include some running-in to achieve homogeneous distribution of the lubricant within the bearing.

7.2 Conditions of the measurement environment

The bearings shall be measured in an environment that does not influence the bearing vibration.

7.3 Conditions for the measuring device

7.3.1 Stiffness of the spindle/mandrel arrangement

The spindle (including the mandrel) used to hold and drive the bearing shall be so constructed that, except for transmission of rotary motion, it represents a rigid reference system for the rotating ring axis. The transmission of vibration between the spindle/mandrel arrangement and the bearing in the frequency band used shall be negligible by comparison to the velocities measured.

7.3.2 Loading mechanism

The loading system used to apply load to the measured ring shall be so constructed that it leaves the ring essentially free to vibrate in all radial, axial, angular or flexural modes according to the bearing type, as long as it allows normal bearing operations.

7.3.3 Magnitude and alignment of the external load applied to the bearing

Details for specific bearing types are given in other parts of ISO 15242.

7.3.4 Axial location of transducer and direction of measurement

Details for specific bearing types are given in other parts of ISO 15242.

7.3.5 Mandrel

The cylindrical surface of the mandrel, on which the inner ring of the bearing is mounted, shall have an outside diameter to tolerance class f5, according to ISO 286-2, with minimal geometric errors. This will ensure a sliding fit in the bearing bore. Radial and axial run-out shall be verified according to the measuring setup given in Annex C.

7.3.6 Others

The measuring system includes additional vibration sources, such as drive motor or oil pumping motor. These vibration sources can affect the vibration values measured. Additional information is given in other parts of ISO 15242.

8 Calibration and reference evaluation of the measuring system

8.1 General

Established calibration procedures shall be followed.

8.2 Calibration of the system components

The basic elements requiring calibration in the bearing vibration measuring system are the following:

- drive unit to rotate the bearing;
- load unit to apply load to the bearing;
- transducer which converts bearing vibration into an electrical signal;
- signal conditioning (amplifier, filter and display device) which processes the signal.

Each part of the measuring system has to be maintained in its originally designed performance condition and adjusted under controlled conditions. The adjustment or calibration shall be traceable to international measurement standards or other national measurement standards. The following are the major calibration and confirmation items for each measuring system:

a) drive unit:
   1) rotational frequency of the spindle;
   2) error motion and residual vibration of the spindle;
   3) condition of the spindle mandrel on which a bearing is mounted (damage, corrosion, deformation, dimensional change, etc.);

b) load unit:
   1) load value;
   2) alignment of the loading direction;
   3) position of the loading point;

c) transducer:
   1) sensitivity and amplitude linearity;
   2) frequency response;
   3) orientation and position;

d) signal conditioning (amplifier, filter and display device):
   1) amplification and linearity;
   2) frequency characteristics;
   3) indication accuracy of the meter or digital display.

8.3 System performance evaluation

Measurements are performed with three bearings using the same measuring equipment and test parameters:

— select properly lubricated reference bearings;

— always measure bearings in the same orientation;

— the reference bearings should always rotate in the same direction;

— unload and load bearing between the measurements. When loading ensure the stationary ring is in same angular position for all measurements;

— repeat at least 10 times with at least three different reference bearings.

For the three bearings, the measuring repeatability for the three bands shall be within ±15 % of the average values of each bearing.

Annex A
(informative)

Contact resonance considerations for spring-loaded transducers

A.1 Contact forces

If the transducer is spring loaded, the contact force shall be greater than $m \times a$ (where m is the moving mass and a is the maximum acceleration to be measured), in order to prevent the transducer from losing contact with the measured ring.

A.2 Contact resonance

Contact resonance is due to the fact that the tip of the transducer behaves like a spring, owing to its modulus of elasticity, E. With a ball ended tip, the situation becomes more complex because the tip acts like a spring with variable stiffness which increases with load. The higher the value of E and the larger the transducer tip radius, r, the higher the value of the resonant frequency, f, becomes. Table A.1 gives some examples for a hemispherical transducer tip (E = 600 GPa) coupled with a transducer to a total moving mass, m, which is pressed onto the surface of the measured ring (E = 200 GPa) with a static force, F.

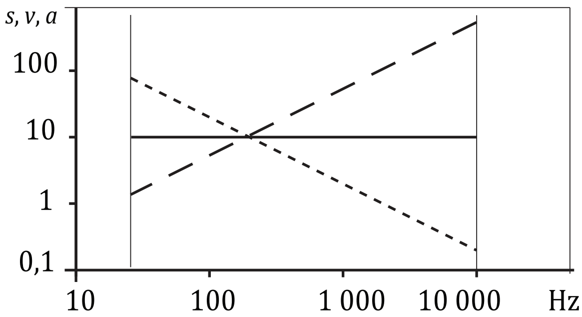
Table A.1 — Frequency of contact resonance

r mm	F N	m g	f kHz
1	1	1	9,6
5	1	1	12,6
1	5	1	12,6
1	1	5	4,3

Annex B
(informative)

Correlation of amplitudes of displacement, velocity and acceleration

Figure B.1 shows the amplitudes of displacement and acceleration at various frequencies corresponding to a constant vibration of 10 µm/s.



Key

- - - - - - - displacement, *s*, nm
——— velocity, *v*, µm/s
— — — acceleration, *a*, mm s^{-2}

Figure B.1 — Correlation of amplitudes for a constant vibration level of 10 µm/s and variable frequency

Annex C
(informative)

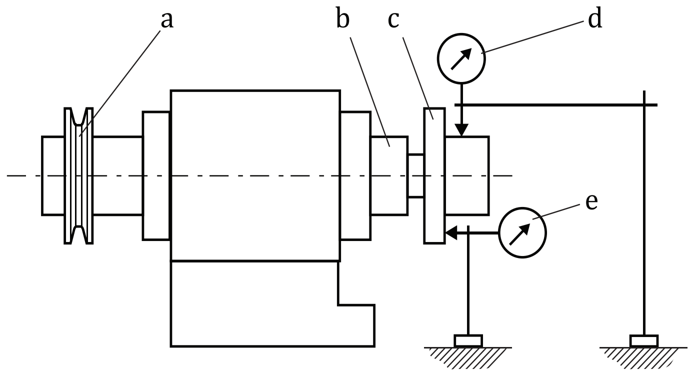
Measurement of radial run-out and axial run-out of the mandrel

Assemble the mandrel into the spindle of the measuring system, as shown in Figure C.1.

Dial indicator 1 (Figure C.1, item d)) shall contact the bearing mounting surface (any location, except the undercut and guiding surface of the bearing assemblies) perpendicular to the mandrel rotational axis.

Dial indicator 2 (Figure C.1, item e)) shall contact the mandrel shoulder (any position, except the undercut and chamfer).

Rotate the spindle slowly and smoothly for more than one revolution. The difference between the maximum and minimum value shown in dial indicator 1 is the radial run-out of the measured position on the mandrel. The difference between the maximum and minimum value shown in dial indicator 2 is the axial run-out of the measured position on the mandrel.



Key

a belt pulley
b spindle
c mandrel
d dial indicator 1
e dial indicator 2

Figure C.1 — Measurement of radial run-out and axial run-out of the mandrel

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