



**International
Standard**

ISO 20816-1

**Mechanical vibration —
Measurement and evaluation of
machine vibration —**

**Part 1:
General guidelines**

*Vibrations mécaniques — Mesurage et évaluation des vibrations
de machines —*

Partie 1: Lignes directrices générales

**Second edition
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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 World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

This second edition of ISO 20816-1 cancels and replaces the first edition (ISO 20816-1:2016), which has been technically revised.

The main changes are as follows:

- Introduction was shortened;
- wording in [Clause 1](#) was aligned with ISO directives;
- references in [Clause 2](#) were updated;
- terms in [Clause 3](#) were added and definitions in [4.3.1](#) removed;
- [Figure 5](#) and [Figure 6](#) were updated;
- [4.8](#) and [4.9](#) were added with content from ISO/TR 19201;
- content of [B.4](#) was deleted and merged with B.5;
- [Figure C.1](#) was added;
- C.2 was removed;
- [Annex E](#) was added with content from ISO/TR 19201;
- wording in the document was aligned with ISO 20816-3;
- Bibliography was updated;
- document editorially revised;

A list of all parts in the ISO 10816 series and the ISO 20816 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

This document establishes general guidelines for the measurement and evaluation of mechanical machine vibration, as measured on rotating and on non-rotating parts of complete machines (e.g. shafts or bearing housings).

Recommendations for measurements and evaluation criteria pertaining to specific machine types are provided in additional parts of the ISO 20816 series as they become available as a replacement of parts of the ISO 10816 series.

For some machines, measurements made on non-rotating parts are sufficient to adequately characterize their running conditions with respect to trouble-free operation. There are also machine types (e.g. steam turbines, gas turbines and turbo compressors) which can have several modes of vibration in their operating speed range, for which measurements on the structure (e.g. bearing housings) do not always fully characterize the running condition of the machine, although such measurements are useful. Such machines generally contain flexible rotor shaft systems and changes in the vibration condition can be detected more effectively by measurements on the rotating elements. Machines having stiff and/or heavy housings in comparison to the rotor mass and/or stiffness are typical of those classes of machines for which shaft vibration measurements are often more appropriate.

Vibration measurements are used for purposes, ranging from routine operational monitoring and acceptance tests to advanced experimental testing as well as diagnostic and analytical investigations. These various measurement objectives lead to many differences in the methods of interpretation and evaluation used. To limit the number of these differences, this document is designed to provide guidelines primarily for use in operational monitoring and acceptance tests.

Three primary vibration quantities (displacement, velocity and acceleration) are defined and their advantages and disadvantages are given.

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Mechanical vibration — Measurement and evaluation of machine vibration —

Part 1: General guidelines

1 Scope

This document establishes general principles for the measurement and evaluation of vibration using measurements made on rotating or non-rotating parts of complete machines. It is applicable to vibration measurements on non-rotating parts and to both absolute and relative radial shaft vibration with regard to the monitoring of radial clearances, but does not apply to axial shaft vibration, unless otherwise stated. The evaluation criteria, which are presented in terms of both vibration magnitude and change in vibration, relate to both operational monitoring and acceptance tests. They have been provided primarily with regard to securing reliable, safe, long-term operation of the machine while minimizing any adverse effects on associated equipment. This document also gives guidance on setting operating limits.

NOTE 1 The evaluation criteria for different machine types are included in other parts of the ISO 10816 series and the ISO 20816 series.

NOTE 2 The term “shaft vibration” is used throughout the ISO 10816 series and the ISO 20816 series because, in most cases, vibration measurements are made on machine shafts. However, the ISO 10816 series and the ISO 20816 series are also applicable to measurements made on other rotating elements of the machine if such elements are found or known to be more suitable, provided that the guidelines set in this document are met.

The evaluation criteria are only applicable to the vibration produced by the machine itself and not the vibration transmitted to it from outside.

This document does not apply to torsional vibration.

NOTE 3 For information regarding the evaluation of torsional vibration, see e.g. ISO 3046-5, ISO 22266-1 or VDI 2039.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 2954, *Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity*

ISO 5348, *Mechanical vibration and shock — Mechanical mounting of accelerometers*

ISO 10817-1, *Rotating shaft vibration measuring systems — Part 1: Relative and absolute sensing of radial vibration*

3 Terms and definitions

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

ISO and IEC maintain terminoly databases for use in standardization at the following addresses:

- IEC Electropedia: available at <https://www.electropedia.org/>
- ISO Online browsing platform: available at <https://www.iso.org/obp>

3.1

shaft absolute vibration

absolute shaft vibration

vibration of rotating parts measured with respect to the absolute coordinate

3.2

shaft relative vibration

relative shaft vibration

vibration of rotating parts measured with respect to the transducer support

3.3

pedestal vibration

vibration measured on the pedestal bearing (a non-rotating part)

3.4

seismic vibration

vibration measured on a non- rotating part

3.5

dynamic stiffness of bearing

stiffness of the bearing part including damping and mass effects

3.6

dynamic stiffness of pedestal

stiffness of the bearing support structure including damping and mass effects

3.7

operational monitoring

measurements made during normal operation of a machine

4 Measurements

4.1 General

4.1.1 Overview

[Clause 4](#) describes the measurements, procedures and operating conditions recommended for assessing machine vibration. The guidelines given enable the evaluation of vibration in accordance with the general criteria and principles given in [Clause 6](#).

The ISO 10816 series and the ISO 20816 series enable the use of different measurement quantities and methods provided that they are well-defined and their advantages and disadvantages are set out so that the interpretation of the measurements is well-understood.

4.1.2 Vibration measurements

It is common practice to measure machine vibration on non-rotating parts or to measure shaft relative vibration, or both. The measurement type to be used for the protection system is usually based on the experience of the machine manufacturer.

4.1.3 Frequency range

Vibration measurement shall be broad-band such that the frequency spectrum of the machine is adequately covered.

The frequency range depends on the machine type being considered (e.g. the frequency range necessary to assess the integrity of rolling bearings should include frequencies higher than those used on machines with fluid-film bearings).

For guidelines for instrumentation frequency ranges for specific machine classes see appropriate parts of the ISO 10816 series and the ISO 20816 series.

NOTE 1 In the past, broad-band measurements in the range from 10 Hz to 1 000 Hz were the intended metric for full-load acceptance tests. This does not always meet the requirements of a condition monitoring scheme and can be modified for the purposes of vibration monitoring and diagnostics.

NOTE 2 For vibration condition monitoring and diagnostics of machines see ISO 13373 series.

For certain machine types (e.g. gearboxes and rolling bearings) it can be appropriate to use a different frequency range for acceptance testing.

4.2 Types of measurement

4.2.1 Vibration measurements on non-rotating parts

Vibration measurements on non-rotating parts are usually taken using a sensor which measures the absolute velocity or acceleration of the structural parts on which it is mounted (e.g. the bearing housing).

4.2.2 Shaft relative vibration measurements

Shaft relative vibration measurements are usually taken using a non-contacting probe which senses the displacement between the shaft and the structural part on which it is mounted (e.g. the bearing housing).

NOTE Displacement probes (e.g. non-contacting eddy current sensors) measure the displacement of the rotor or shaft. The AC portion of the signal is directly proportional to the shaft relative vibration.

4.2.3 Shaft absolute vibration measurements

Shaft absolute vibration measurements are taken using either

- a) a shaft-riding probe on which a vibration sensor is mounted so that it measures shaft absolute vibration directly, or
- b) a non-contacting displacement probe which measures shaft relative vibration in combination with a seismic vibration sensor which measures the housing vibration. Both transducers shall be mounted close together such that they undergo the same vibration in the direction of measurement. Their conditioned outputs are summed to provide a measurement of the shaft absolute vibration. To avoid incorrect results, the same time reference shall be used for the outputs from both the seismic and non-contacting displacement probes (i.e. synchronous sampling). If this cannot be achieved, the magnitude of the resulting error shall be assessed.

4.3 Measurement parameters

4.3.1 Measurement quantities

For the purposes of this document, these measurement quantities can be used:

- a) displacement measured in μm ;
- b) velocity measured in mm/s ;
- c) acceleration measured in m/s^2 .

The use, application and limitations of these quantities are discussed in [Clause 6](#).

There is no simple relationship between broad-band acceleration, velocity and displacement; nor is there between peak (0-p), peak-to-peak (p-p), root-mean-square (r.m.s.) and average magnitudes of vibration. The reasons for this are briefly discussed in [A.1](#), which also defines some precise relationships between the quantities when the harmonic content of the vibration waveform is known.

To avoid confusion and to enable correct interpretation, the measurement quantity and its unit shall be clearly identified (e.g. peak-to-peak displacement in μm , r.m.s. velocity in mm/s or peak-to-peak shaft absolute displacement in μm).

NOTE Vibration is a vector quantity and therefore, when comparing two different vibration measurements, it can be necessary to consider the phase angle between them (see [Annex D](#)).

The preferred measurement quantity for the measurement of vibration of non-rotating parts is r.m.s. velocity while the preferred measurement quantity for the measurement of shaft vibration is peak-to-peak displacement.

It shall be clearly indicated in measurements taken whether shaft displacement magnitudes are relative or absolute.

Relative and absolute displacements are further defined by several different displacement quantities, each of which is in widespread use. These include:

s_{max} maximum shaft displacement in the plane of measurement, measured from its time integrated mean position, see [Formula \(A.12\)](#);

$s_{(\text{p-p})}$ peak-to-peak shaft displacement in the direction of measurement defined as $s_{(\text{p-p})} = \max \{s_{A,(\text{p-p})}, s_{B,(\text{p-p})}\}$; and

$s_{(\text{p-p}),\text{max}}$ maximum shaft peak-to-peak displacement in the plane of measurement.

Any of these displacement quantities may be used for the measurement of shaft vibration. The relationships between these quantities are shown in [Figure A.3](#).

4.3.2 Vibration magnitude

The result of measurements made with an instrument which complies with the requirements of [Clause 5](#) is the vibration magnitude at a specific measurement position and direction.

It is common practice, when evaluating the broad-band vibration of rotating machines, to consider the r.m.s. magnitude of velocity since it can be related to the vibration energy. However, other quantities (e.g. displacement or acceleration and peak magnitudes instead of r.m.s. magnitudes) can be preferred. In this case, alternative evaluation criteria, which are not necessarily simply related to r.m.s. magnitudes, are required.

For shaft vibration measurement, it is common practice to consider peak-to-peak magnitudes.

4.3.3 Vibration severity

Usually, measurements are made at various measurement positions and in one, two or three measurement directions, leading to a set of different vibration magnitudes. The maximum broad-band magnitude measured under the agreed machine support structure and operating conditions is defined as the vibration severity (see also ISO 2041).

For most machine types, one value of vibration severity characterizes the vibratory state of that machine. However, for some machines, this approach is inadequate and the vibration severity shall then be assessed independently for measurement positions at several locations.

4.4 Measurement positions and directions

4.4.1 Preferred measurement positions and directions on non-rotating parts

Measurements on non-rotating parts shall be taken on the bearings, the bearing support structure, the bearing housing or other structural parts which significantly respond to the dynamic forces transmitted from the rotating elements at the bearing locations and characterize the overall vibration of the machine. Typical measurement positions are shown in [Figure 1](#) to [Figure 5](#).

To determine the vibrational severity at each measurement position, it is necessary to take measurements in three mutually perpendicular directions. The full complement of measurements represented in [Figure 1](#) to [Figure 5](#) is generally only required for acceptance tests.

The requirements for operational monitoring are usually met by performing one or both measurements in the radial direction (usually taken in the horizontal/transverse and/or vertical directions). These can be supplemented by a vibration measurement in the axial direction. The severity of an axial measurement is only evaluated at locations representative of thrust bearings where direct axial dynamic forces are transmitted.

A single radial vibration sensor may be used on a bearing housing or pedestal in place of the more typical pair of orthogonal sensors if it is known to provide adequate information about the machine's vibration magnitude. The positioning of the sensor shall be such that it provides a reasonable approximation of the maximum magnitude in that plane.

When a single triaxial accelerometer is used, only those axes which are in line with the measurement positions defined in this document shall be compared with the guidelines given in other parts of the ISO 20816 series. In particular, a triaxial measurement taken at the top of the bearing is likely to over-estimate axial and transverse vibration magnitudes. The magnitudes remain useful for trending purposes as part of a condition monitoring programme.

When a vibration sensor is attached using a bracket, it shall be confirmed that no resonances of the bracket are affecting the measurement.

Detailed recommendations for specific machine types are provided in the additional parts of the ISO 10816 series and the ISO 20816 series.

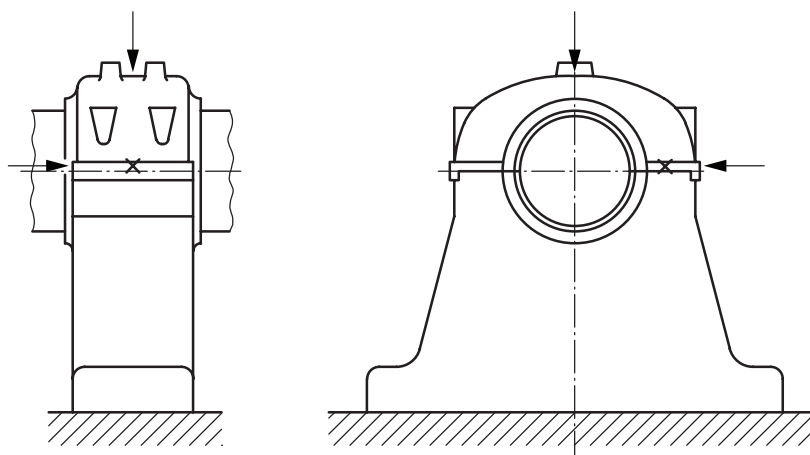


Figure 1 — Preferred measurement positions and directions for pedestal bearings

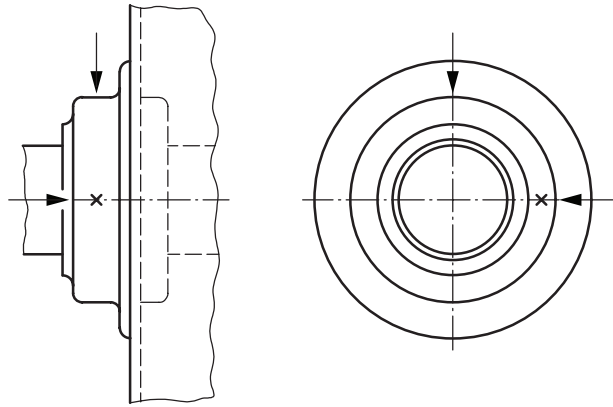


Figure 2 — Preferred measurement positions and directions for bearing housings

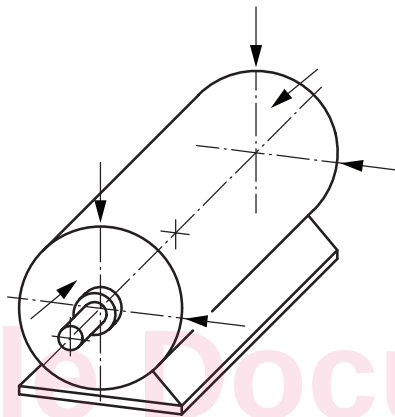


Figure 3 — Preferred measurement positions and directions for machines

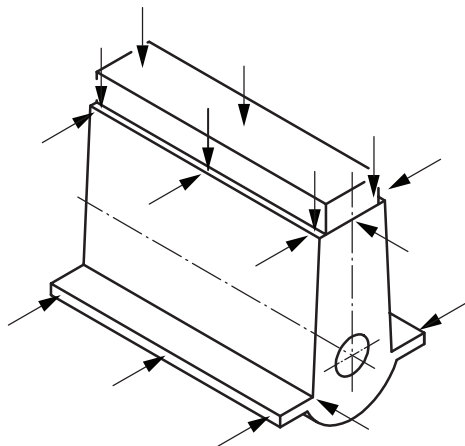


Figure 4 — Preferred measurement positions and directions for reciprocating engines close to the bearing locations

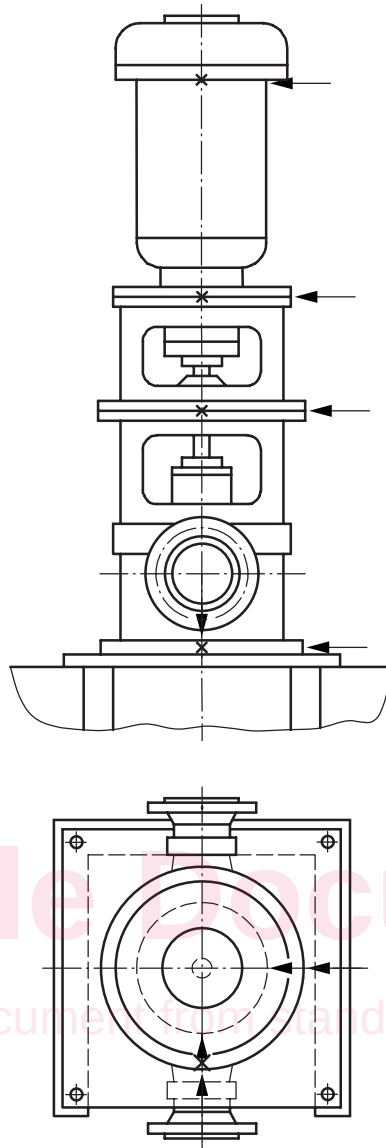


Figure 5 — Preferred measurement positions and directions for vertical machine sets

4.4.2 Preferred measurement positions on rotating shafts

4.4.2.1 General

For the measurements on rotating shafts, the displacement probes shall be mounted at positions such that the radial movement of the shaft at positions of importance can be assessed. It is recommended that, for both relative and absolute measurements, two probes shall be located at, or adjacent to each machine bearing (see [Figure 6](#)). They shall be radially mounted in the same plane perpendicular to the shaft axis or as close as is practicable, with their axes within $\pm 5^\circ$ of a radial line. A pair of probes shall be mounted $90^\circ \pm 5^\circ$ apart from each other on the same bearing half and the positions chosen shall be, if possible, the same at each bearing (see [Figure 7](#)).

A single displacement probe may be used at each measurement plane instead of the more typical pair of orthogonal probes if that is known to provide adequate information regarding shaft vibration.

The positioning of the probe shall be such that it provides a reasonable approximation of the maximum magnitude in that plane.