INTERNATIONAL STANDARD

ISO 20816-9

First edition
2020-06

Mechanical vibration — Measurement and evaluation of machine vibration —

Part 9: Gear units

Vibrations mécaniques — Mesurage et évaluation des vibrations de machines —
Partie 9: Engrenages

Reference number
ISO 20816-9:2020(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword ..... **iv**
Introduction ..... **v**
1 Scope **1**
2 Normative references **1**
3 Terms and definitions **2**
4 General **2**
4.1 System considered 2
4.2 Effects of the system 2
4.3 Housing or shaft measurements 2
5 Instrumentation **3**
5.1 Type 3
5.1.1 General instrumentation requirements 3
5.1.2 Shaft measurement instrumentation 3
5.1.3 Housing measurement instrumentation 3
5.2 Measurement frequency range 4
5.3 Permissible errors 4
5.4 Calibration 4
6 Vibration measurements **4**
6.1 Shaft measurements 4
6.2 Housing measurements 5
6.3 Units of measurement 5
7 Test conditions **5**
7.1 General 5
7.2 Arrangement of the test system 5
7.2.1 Manufacturer's shop test 5
7.2.2 On-site acceptance tests 6
7.2.3 In-service monitoring 6
7.3 Test conditions 6
8 Evaluation criteria **6**
8.1 General 6
8.2 Evaluation zones 6
8.3 Acceptance criteria 7
8.4 Vibration evaluation zone boundaries 7
8.5 Classifications 9
9 Test report **9**
9.1 General 9
9.2 Manufacturer 9
9.3 Operating data 9
9.4 Description of the arrangement 10
9.5 Measuring equipment 10
9.6 Test measurements and results 10
9.7 Acceptance test approval 10
Annex A (informative) **Rating curves for vibration displacement and velocity measurements** **11**
Annex B (informative) **Effects of the system** **15**
Annex C (informative) **Vibration instruments and characteristics considerations** **17**
Bibliography **19**

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 of the voluntary nature of standards, 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 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 first edition of ISO 20816-9 is a technical revision of ISO 8579-2:1993, which was withrdrawn in 2016.

The main changes compared to ISO 8579-2:1993 are as follows:

— It has been re-formatted to match other parts of the ISO 20816 series and includes zones A to D.

— It has two new tables for values of vibration and displacement at zone boundaries.

— A table with values for vibration acceleration rating at zone boundaries has also been included.

— The classifications table has been revised, referring to these new rating tables.

— The displacement and velocity rating graphs have been moved into an informative annex.

A list of all parts in 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.

Introduction

ISO 20816-1 is the part of the ISO 20816 series that gives the general requirements for evaluating the vibration of various machine types when the vibration measurements are made on both non-rotating parts and rotating shafts.

ISO 20816-9 (this document) provides specific provisions for assessing the vibration of individually housed, enclosed, speed increasing or speed reducing gear units. It can be used for acceptance testing, and, by agreement between manufacturer and customer and/or operator, for guidance for routine operational measurements.

Guidance is provided for assessing the vibration of gear units when operating under steady-state conditions and considering the magnitude of the observed vibration. However, no criteria are provided for transient operating conditions.

The evaluation procedures presented in this document are based on broad-band measurements. However, because of advances in technology, the use of narrow-band measurements or spectral analysis has become increasingly widespread, particularly for the purposes of vibration evaluation, condition monitoring and diagnostics. The specification of criteria for such measurements is beyond the scope of this document. They are provided in greater detail in the relevant parts of the ISO 13373 series which establish requirements for the vibration condition monitoring of machines.

Mechanical vibration — Measurement and evaluation of machine vibration —

Part 9: Gear units

1 Scope

This document specifies requirements for determining and classifying mechanical vibration of individually housed, enclosed, speed increasing or speed reducing gear units. It specifies methods for measuring housing and shaft vibrations, and the types of instrumentation, measurement methods and testing procedures for determining vibration magnitudes. Vibration grades for acceptance are included.

Torsional vibration measurements are outside the scope of this document.

It applies to a gear unit operating within its design speed, load, temperature and lubrication range for acceptance testing at the manufacturer's facility. By agreement between manufacturer and customer and/or operator, it can be used for guidelines for on-site acceptance testing and for routine operational measurements.

This document applies to gear units of nominal power rating from 10 kW to 100 MW and nominal rotational speeds between 30 r/min and 12 000 r/min (0,5 Hz to 200 Hz).

This document does not apply to special or auxiliary drive trains, such as integrated gear-driven compressors, pumps, turbines, etc., or gear type clutches used on combined-cycle turbo generators and power take-off gears.

The evaluation criteria provided in this document can be applied to the vibration of the main input and output bearings of the gearbox and to the vibration of internal shaft bearings. They can have limited application to the evaluation of the condition of those gears. Specialist techniques for evaluating the condition of gears are outside the scope of this document.

This document establishes provisions under normal steady-state operating conditions for evaluating the severity of the following *in-situ* broad-band vibration:

a) structural vibration at all main bearing housings or pedestals measured radially (i.e. transverse) to the shaft axis;

b) structural vibration at thrust bearing housings measured in the axial direction;

c) vibration of rotating shafts radially (i.e. transverse) to the shaft axis at, or close to, the main bearings;

d) structural vibration on the gear casing.

NOTE Vibration occurring during non-steady-state conditions (when transient changes are taking place), including run up or run down, initial loading and load changes are outside the scope of this document.

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 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 terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
gear unit
mechanical input/output device with a series of at least two meshing gears

4 General

4.1 System considered

For manufacturer's factory testing, the gear unit shall be measured and tested in such a manner as to minimize, as far as possible, effects of the system (see Annex B). For in-field service testing, the driver and driven machine components, mounting and other factors can influence the vibration of the gear unit. Other International Standards and vibration evaluation can be required for measuring the driver or driven machine when operating in-field service.

4.2 Effects of the system

Vibration magnitudes of the gear unit in field service can be adversely affected by factors beyond the control of the gear unit manufacturer, as listed in Annex B. It is preferable to estimate the vibration of the whole system and to check the system effects at the initial design stage of a transmission system. The responsibility for checking should be clearly defined during this stage and all interested parties made aware of the decision.

4.3 Housing or shaft measurements

The vibrations of a gear unit can be measured in two ways, i.e. on the housing (casing) or relative to the shafts. Housing vibration measurements are preferred for gear units operating with rolling element bearings when the clearance in such bearings is small and little relative movement normally occurs between the shaft and housing.

Both shaft and housing vibration measurements are usually made on gear units operating with plain journal bearings (fluid-film bearings). Shaft vibration measurements can provide detailed information which is sometimes not evident from housing measurements, but only over a limited frequency range (typically up to 500 Hz).

Care shall be taken when choosing the measurement instrument to be used for a given gear unit and operating conditions, as each instrument has its own characteristics (see Annex C). Where possible, it is useful to combine both shaft and housing vibration measurements to obtain the absolute motion of a gear or a shaft.

When operating conditions during acceptance testing deviate considerably from field service, the differences shall be taken into account in the assessment of vibration data.

5 Instrumentation

5.1 Type

5.1.1 General instrumentation requirements

Vibration shall be measured using instrumentation capable of measuring broad-band acceleration, velocity and/or displacement, as appropriate, over frequency ranges specified below.

Care should be taken to ensure that the measuring system is not influenced by environmental factors such as:

— temperature variations;

— magnetic fields;

— surface finish;

— power source variations;

— transducer cable length;

— transducer orientation.

Particular attention should be given to ensure that the vibration transducers are correctly mounted and that such mountings do not degrade the accuracy of the measurements.

The type and use of vibration instrumentation systems shall conform to ISO 2954 for housing vibration measurement and shall conform to ISO 10817-1 for shaft vibration measurement. The instrumentation should preferably include a facility for time and spectral frequency analysis.

5.1.2 Shaft measurement instrumentation

The recommended type of transducer for measuring relative shaft vibration is a non-contacting transducer or proximity probe.

The instrument shall allow a reading of peak or peak-to-peak values of vibration displacement to be taken.

NOTE Shaft-riding transducers are no longer in common use, but if fitted, can be acceptable if the rotational frequency of the shaft is less than 3 000 r/min, the signal frequency is less than 200 Hz, and surface rubbing velocity is less than 30 m/s.

5.1.3 Housing measurement instrumentation

The recommended type of transducer for measuring housing vibration is a seismic transducer measuring velocity or acceleration. In order to measure acceleration, velocity and displacement, it is preferable to use an accelerometer. The instrumentation used to acquire the signal should be capable of displaying the root-mean-square (RMS) values of vibration velocity in millimetres per second and the true peak values of vibration acceleration in metres per second per second. The mounting method can affect the frequency response of the transducer; it should therefore preferably be mounted with a screw or stud or using a suitable bonding material. Magnet-mounted accelerometers can be acceptable if the highest fundamental frequency of tooth meshing is less than 2 000 Hz. Hand-held housing measurements are not acceptable for acceptance testing.

NOTE Information on mounting transducers is contained in ISO 5348 and ISO 13373-1.

5.2 Measurement frequency range

The instrumentation shall be capable of measuring from half the lowest shaft rotational speed to at least 3,5 times the highest tooth mesh frequency.

The shaft displacement frequency measurement range shall be from 2 Hz to at least 500 Hz. The housing velocity frequency measurement range shall be from 10 Hz to at least 2 000 Hz. The acceleration frequency measurement range shall be from 10 Hz to 5 000 Hz. If a component rotational speed or tooth meshing frequency occurs outside these ranges, revised frequency ranges shall be agreed between the gear unit manufacturer and customer and/or operator.

5.3 Permissible errors

The measuring instrumentation system, including both the transducer and instrumentation, shall be capable of indicating the vibration magnitude within a permissible error of ±10 % of the reading over the entire operating frequency range.

NOTE Guidance on transducer selection is given in ISO 13373-1.

5.4 Calibration

For acceptance testing, the vibration instrumentation shall be checked against a reference signal and any specified adjustments made immediately before and rechecked immediately after each series of gear unit acceptance vibration measurements have been taken.

For in-situ measurements, calibration of the complete measuring equipment system should be carried out regularly as specified by the instrumentation supplier. Calibrations are typically valid for one to five years.

NOTE 1 Guidance on transducer calibration by comparison is given in ISO 16063-21.

NOTE 2 Guidance on transducer in-situ calibration is given in ISO 16063-44.

6 Vibration measurements

6.1 Shaft measurements

Vibration displacement of the shafts should be measured relative to the housing. Non-contacting transducers (proximity probes) are normally used to measure radial vibration displacement, fitted in orthogonal pairs through the journal bearing housing. Shaft vibration can also be measured axially, especially when fluid-film thrust bearings are fitted. The number and location of transducers shall be agreed between the gear unit customer and manufacturer. Guidance on mounting proximity probes is given in ISO 10817-1.

Prior to running the gear unit up to its rated speed(s), slow-roll measurements of shaft displacement may be carried out. If so, the measurement system needs to be capable of measuring down to low frequencies (e.g. <5 Hz). Such measurements cannot normally be regarded as giving a valid indication of shaft runout under normal operating conditions, since they can be affected by, for example, temporary bows, erratic movements of the shaft within the bearing clearance, and axial movements. Subtraction of slow-roll measurements from rated-speed vibration measurements should not be carried out without careful consideration of these factors, since the results can provide a misleading interpretation of the machine vibration.

The combined mechanical and electrical runout should not exceed 25 % of the allowable vibration displacement at the shaft rotational frequency, or 6 µm, whichever is greater.

6.2 Housing measurements

Housing vibration shall be measured on a rigid housing section such as a bearing block. Measurements should not be made on housing sections which do not support bearings or are not rigid, since they will not provide a true indication of gear unit vibration. Measurements shall be taken in up to three orthogonal directions, two of which lie in a plane perpendicular to the rotating axis of the gears. If the load zone of the bearing is known, it is preferable to measure radially in this direction; otherwise horizontal, vertical and axial are the preferred measurement directions. Axial measurements can give additional information on faults such as gear misalignment and unbalance.

It is recommended that measurements be taken at each accessible bearing location on a gear unit. If a bearing block is inaccessible, then the nearest mounting point may be used giving due consideration to the transmission path from the bearing to this location. The number and location of transducers shall be agreed between the manufacturer and customer and/or operator.

6.3 Units of measurement

The preferred units of measurement are given in Table 1.

Table 1 — Units of measurement

Quantity	Unit
Displacement (peak-to-peak)	µm
Velocity (RMS)	mm/s
Acceleration (peak)	m/s^2
Frequency	Hz

7 Test conditions

7.1 General

The measurement of vibration on a gear unit can be conducted during:

a) manufacturer's shop test;

b) on-site acceptance testing;

c) in-service monitoring.

Special provisions can be required for vibration measurements in each case. The type of measurement and acceptance values for each case should be agreed between the manufacturer and customer at an early stage of negotiation.

7.2 Arrangement of the test system

7.2.1 Manufacturer's shop test

The mechanism for driving the gearbox during a shop test shall be the gear unit manufacturer's responsibility unless otherwise negotiated with the customer and/or operator.

The test transmission, driver, gear unit and any load applied shall be connected by the in-service couplings or by couplings with similar effective overhung masses. The gear unit can be tested with no-load or with a light load to stabilize operation or in accordance with the conditions set out in 7.3.