PD ISO/TR 19201:2013

BSI Standards Publication

Mechanical vibration — Methodology for selecting appropriate machinery vibration standards

bsi.

...making excellence a habit.™

Document Sharing Hub

National foreword

This Published Document is the UK implementation of ISO/TR 19201:2013.

The UK participation in its preparation was entrusted to Technical Committee GME/21/5, Mechanical vibration, shock and condition monitoring - Vibration of machines.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2013. Published by BSI Standards Limited 2013

ISBN 978 0 580 79279 3

ICS 17.160

Compliance with a British Standard cannot confer immunity from legal obligations.

This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 July 2013.

Amendments issued since publication

Date	Text affected

Documents
Document Sharing Hub

Full document details: PD ISO/TR 19201:2013

TECHNICAL REPORT

ISO/TR 19201

First edition
2013-06-01

Mechanical vibration — Methodology for selecting appropriate machinery vibration standards

Vibrations mécaniques — Méthodologie pour la sélection des normes appropriées relatives aux vibrations des machines

Reference number
ISO/TR 19201:2013(E)

Documents
Document Sharing Hub

© ISO 2013

Full document details: PD ISO/TR 19201:2013

COPYRIGHT PROTECTED DOCUMENT

© ISO 2013

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

© ISO 2013 – All rights reserved

Documents
Document Sharing Hub

Full document details: PD ISO/TR 19201:2013

Contents

Page

Foreword ..... **iv**

1 Scope **1**

2 International Standards **1**
2.1 Basic machinery vibration standards 1
2.2 Related machinery vibration standards 2
2.3 Additional machinery vibration standards 2

3 Terms and definitions **3**

4 Evaluation of machine vibration **3**
4.1 General 3
4.2 Machinery vibration standards and criteria 3
4.3 Classification of severity of machine vibration 4
4.4 Measurement procedures and instrumentation 4
4.5 Vibration standards summaries 4

5 Measurements made on non-rotating parts **5**

6 Measurements made on rotating parts **8**

7 Related standards **9**

8 Analytical guidelines for selecting the appropriate vibration standard for specific machinery **11**
8.1 General 11
8.2 Basic relations for rotating shaft and pedestal vibration 14

Annex A (informative) **Bearing dynamics** **16**

Annex B (informative) **Pedestal dynamic stiffness** **19**

Annex C (informative) **Examples of typical values of dynamic stiffness for bearings and pedestals** **20**

Annex D (informative) **Dynamic stiffness of the bearing part combined with the pedestal** **22**

Annex E (informative) **International machinery vibration standards shown by application area** **24**

Bibliography **28**

© ISO 2013 – All rights reserved

Documents
Document Sharing Hub
Full document details: PD ISO/TR 19201:2013

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, 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, 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.

The committee responsible for this document is 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*.

© ISO 2013 – All rights reserved
Documents
Document Sharing Hub
Full document details: PD ISO/TR 19201:2013

Mechanical vibration — Methodology for selecting appropriate machinery vibration standards

1 Scope

This Technical Report provides guidance for selecting appropriate vibration standards for specific machine types, and thus selecting the appropriate vibration measurement and evaluation method. Synopses are given of ISO 10816 (evaluation of machine vibration on non-rotating parts) and ISO 7919 (evaluation of machine vibration on rotating parts), together with further International Standards related to machinery.

This Technical Report provides an overview of the relevant International Standards, giving a summary of their scopes. It also provides a theoretical, analytical basis for establishing whether vibration measurements should be carried out on non-rotating parts, rotating shafts or both for those machines where no previous experience exists. It is not intended to supersede established manufacturers' or users' practical experience with specific machine types since there can be specific features associated with a particular machine which lead to a different selection of the most relevant measurement procedure.

The aim of this Technical Report is not to equip the reader with all the technical details provided in the International Standards necessary to carry out a measurement or evaluation task on a particular machine; rather it guides the reader to the appropriate International Standards. It is these International Standards that provide the necessary details; and then, with suitable training, the reader is in a position to carry out the measurement or evaluation task.

2 International Standards

NOTE 1 The International Standards referred to in this Technical Report are periodically reviewed. Care needs to be taken when using the International Standards presented to ensure that the latest edition (including any Amendments and Corrigenda) is used.

NOTE 2 Many of the International Standards discussed in this Technical Report together with additional International Standards are summarized by their application area in Table E.1.

NOTE 3 This Technical Report provides a snapshot of current relevant standards. It is inevitable, however, that as time passes new standards will be developed. Furthermore, there may be other standards available for specific machine types which have not been referred to. The absence of any such reference should not be interpreted as meaning that such standards are not valid.

2.1 Basic machinery vibration standards

ISO 7919-1, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 1: General guidelines*

ISO 7919-2, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min*

ISO 7919-3, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 3: Coupled industrial machines*

ISO 7919-4, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 4: Gas turbine sets with fluid-film bearings*

ISO 7919-5, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 5: Machine sets in hydraulic power generating and pumping plants*

Documents
Document Sharing Hub

© ISO 2013 – All rights reserved

Full document details: PD ISO/TR 19201:2013

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

ISO 10816-2, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 2: Land-based steam turbines and generators in excess of 50 MW with normal operating speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min*

ISO 10816-3, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min when measured in situ*

ISO 10816-4, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 4: Gas turbine sets with fluid-film bearings*

ISO 10816-5, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 5: Machine sets in hydraulic power generating and pumping plants*

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

ISO 10816-7, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 7: Rotodynamic pumps for industrial applications, including measurements on rotating shafts*

ISO 10816-8, *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts — Part 8: Reciprocating compressor systems*

2.2 Related machinery vibration standards

ISO 3046-5, *Reciprocating internal combustion engines — Performance — Part 5: Torsional vibrations*

ISO 8579-2, *Acceptance code for gears — Part 2: Determination of mechanical vibrations of gear units during acceptance testing*

ISO 13373-1, *Condition monitoring and diagnostics of machines — Vibration condition monitoring — Part 1: General procedures*

ISO 13373-2, *Condition monitoring and diagnostics of machines — Vibration condition monitoring — Part 2: Processing, analysis and presentation of vibration data*

ISO 13373-3,[1)]*Condition monitoring and diagnostics of machines — Vibration condition monitoring — Part 3: Guidelines for vibration diagnosis*

ISO 14694, *Industrial fans — Specifications for balance quality and vibration levels*

ISO 14695, *Industrial fans — Method of measurement of fan vibration*

2.3 Additional machinery vibration standards

ISO 1925, *Mechanical vibration — Balancing — Vocabulary*[2)]

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*

1) Planned.

2) To become ISO 21940-2 when revised.

© ISO 2013 – All rights reserved
Documents
Document Sharing Hub
Full document details: PD ISO/TR 19201:2013

ISO 21940-31, *Mechanical vibration — Rotor balancing — Part 31: Susceptibility and sensitivity of machines to unbalance*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 1925 and ISO 2041, and the following apply.

3.1
shaft absolute vibration
vibration of the shaft measured from the absolute coordinate

3.2
shaft relative vibration
vibration of the shaft measured from the transducer support (e.g. bearing housing)

3.3
pedestal vibration
bearing support structure vibration

3.4
dynamic stiffness of bearing
stiffness of the bearing part including damping and mass effects

3.5
dynamic stiffness of pedestal
stiffness of the bearing support structure including damping and mass effects

4 Evaluation of machine vibration

4.1 General

ISO 10816 provides guidelines for the measurement and evaluation of vibration for different machine types based on measurements made on non-rotating parts of the machines.

ISO 7919 provides guidelines for the measurement and evaluation of vibration based on measurements made on rotating shafts of the machines.

Further guidance is provided in the related and additional machinery vibration standards listed in 2.2 and 2.3.

4.2 Machinery vibration standards and criteria

Machinery can be subdivided into four categories for the purposes of vibration measurement and evaluation.

a) *Reciprocating machinery having both rotating and reciprocation components*, such as diesel engines and certain types of compressors and pumps. The vibration is usually measured on the main structure of the machine at low frequencies, typically in the range 2 Hz to 1 000 Hz.

b) *Rotating machinery having rotors with rigid behaviour*, such as certain types of electric motors, single-stage pumps and low rotational speed pumps. The vibration is usually measured on the main structure (such as on the bearing caps or pedestals) where the vibration magnitudes are indicative of the excitation forces generated by the rotor because of unbalance, thermal bows, rubs and other sources of excitation.

c) *Rotating machinery having rotors with flexible behaviour*, such as large steam and gas turbine generator sets, multi-stage pumps and compressors. The machine may be set into different modes of vibration as it accelerates through one or more resonance rotational speeds to reach its service rotational speed. On such a machine, the vibration magnitude measured on a structural member may

© ISO 2013 – All rights reserved

AVA Documents
Document Sharing Hub
Full document details: PD ISO/TR 19201:2013

not be totally indicative of the vibration of the rotor. For example, a flexible rotor may experience very large displacements resulting in failure of the machine, even though the vibration magnitude measured on the bearing cap is low. Therefore, it can be necessary to measure the vibration of the shaft directly.

d) *Rotating machinery having rotors with quasi-rigid behaviour*, such as some steam turbine rotors, axial-flow compressors, and fans. Such machinery contains a special class of flexible rotor where vibration magnitudes measured on the bearing cap are indicative of the shaft vibration.

An analytical approach to determine the most beneficial vibration measurement method (or International Standard) to use on a particular machine, based on the physical and structural characteristics of the machine, is included in detail in Clause 8.

4.3 Classification of severity of machine vibration

In the classification of severity of machine vibration, the motion variable that is used (displacement, velocity or acceleration) depends on the applicable International Standard, the frequency range and other factors. In classifying machinery vibration in a range, e.g. 10 Hz to 1 000 Hz, vibration velocity is normally used because it yields a simple measure of the vibration severity of a machine. For lower- and higher-frequency vibration, the preferred measurement quantities are displacement and acceleration, respectively.

For simple harmonic motion, either peak or root mean square (r.m.s.) values of the motion variable may be used. However, for machines whose motion is complex, the use of these two metrics provides distinctly different results, mainly because of particular waveforms such as pulse-like waves or higher-frequency harmonics and are given different weights. For rotating machinery whose rotational speed is in the range 600 r/min to 12 000 r/min, the r.m.s. values of vibration velocity correspond most closely with vibration severity. Therefore, there is a special measure, vibration severity, which has been defined in the past as the highest value of the broadband r.m.s. value of the velocity magnitude in the frequency range 10 Hz to 1 000 Hz, as evaluated on the structure at prescribed points as defined in the relevant standard for that machine type (e.g. ISO 10816-2).

NOTE Nowadays vibration severity is a general term for the maximum measured vibration value on non-rotating parts of a machine, irrespective of whether it is displacement, velocity or acceleration (see ISO 2954).

4.4 Measurement procedures and instrumentation

Included in the referenced International Standards are procedures for measuring relative shaft-to-housing signals, absolute measurements and seismic applications.

The transducers recommended and described include displacement, velocity and acceleration; their mounted and unmounted ranges and limits of application, magnitudes and frequencies are included. ISO 2954 provides specifications of instruments measuring vibration of machinery housings. ISO 5348 provides recommendations for mounting accelerometers to the machinery housing, which in most cases are also applicable to velocity transducers. ISO 10817-1 describes the sensing device (transducer), signal conditioning, attachment methods and calibration procedures for instrumentation to measure shaft vibration.

4.5 Vibration standards summaries

Clauses 5 and 6 contain brief descriptions of the most prominent machinery vibration standards, either issued or under development. They contain broadband measurement procedures and limit values and zones. Clause 5 includes: measurements on non-rotating parts; reciprocating machines; measurements on non-reciprocating rotating shafts; and machines having gear units. Clause 6 includes similar measurement procedures, limit values and zones on rotating shafts. Also considered are measurements on machines with rotors with rigid or flexible behaviour. Consult each individual International Standard for details regarding machinery type and size and vibration limits for zones of operation, from acceptable to critical.

Clause 7 includes brief summaries of related International Standards besides ISO 7919 and ISO 10816.

© ISO 2013 – All rights reserved
Documents
Document Sharing Hub
Full document details: PD ISO/TR 19201:2013

5 Measurements made on non-rotating parts

5.1 ISO 10816-1 provides general guidelines that describe procedures for the measurement and evaluation of vibration based on measurements made on non-rotating parts of the machine. This is the first part of a series of International Standards that provide individual criteria for each general class of machine covered, which are unique to those machines. These criteria, which are presented in terms of both vibration magnitude and change of vibration, relate to operational monitoring and acceptance testing.

ISO 10816 accomplishes the following:

a) coverage of the broadband frequency range of both low and high rotational speed machines;

b) setting of vibration criteria to include various operational zones;

c) incorporation of vibration criteria derived from a worldwide survey;

d) inclusion of unique criteria and measurement procedures for specific types of machines.

General guidelines for establishing evaluation zones under steady-state operating and transient conditions are described. These provide the basis for the machine-specific evaluation criteria in the subsequent parts of ISO 10816. The zones are defined as follows.

Zone A. The vibration of newly commissioned machines normally falls within this zone.

Zone B. Machines with vibration within this zone are normally considered acceptable for unrestricted long-term operation.

Zone C. Machines with vibration within this zone are normally considered unsatisfactory for long-term continuous operation. Generally, the machine may be operated for a limited period in this condition until a suitable opportunity arises for remedial action.

Zone D. Vibration values within this zone are normally considered to be of sufficient severity to cause damage to the machine.

The vibration limits for the zone boundaries provide guidelines for ensuring that gross deficiencies or unrealistic requirements are avoided. Acceptance criteria shall always be subject to agreement between the machine supplier and purchaser prior to installation. The evaluation zones provide a basis for defining acceptance criteria for new or refurbished machines. Historically, acceptance criteria have been specified in zone A or zone B but would normally not exceed 1,25 times the zone boundary A/B.

The measure of vibration is broadband and the frequency range is sufficient to ensure that the particular machine is adequately covered, which depends on the type of machine under consideration, e.g. the frequency range necessary to assess the integrity of a machine with rolling element bearings should include frequencies higher than those on machines with fluid-film bearings. In addition to vibration velocity measurements, which were the primary criteria in earlier International Standards because they related to vibration energy, ISO 10816 also includes alternative criteria such as displacement, acceleration and peak values instead of r.m.s., as these criteria may be preferred for machines designed for extra low or high rotational speed operation.

5.2 ISO 10816-2 provides specific guidance for assigning the severity of vibration measured on the bearings or pedestals of large steam turbine generator sets. Measurements at such specified locations reasonably characterize the overall state of vibration of these machines.

The vibration measurement system should be capable of measuring broadband r.m.s. vibration over a frequency range from at least 10 Hz to 500 Hz. If, however, the instrumentation is also to be used for diagnostic purposes, or for monitoring during machine run-up or run-down, or overspeed, a wider frequency range may be required.

ISO 10816-2 includes the vibration criteria that are based on bearing housing or pedestal r.m.s. vibration velocity for steam turbine generator sets exceeding 50 MW, and with nominal rotational speeds of 1 500 r/min, 1 800 r/min, 3 000 r/min and 3 600 r/min. The values apply to *in situ* application under steady-

© ISO 2013 – All rights reserved

Documents
Document Sharing Hub
Full document details: PD ISO/TR 19201:2013

state conditions and they address various zones of operation. The zone descriptions are the same as in ISO 10816-1. Transient operating conditions, such as load and rotational speed changes, are also covered.

5.3 ISO 10816-3 provides specific guidance for assessing the severity of vibration on bearings, bearing pedestals or the housings of coupled industrial machines when measured *in situ*. ISO 10816-3 covers steam turbines up to 50 MW and steam turbine sets with power greater than 50 MW and rotational speeds below 1 500 r/min or above 3 600 r/min. Also included are compressors, industrial gas turbines with power up to 3 MW, generators (other than those covered by ISO 10816-2), electric motors of any type, and all blowers and fans with power greater than 300 kW and other fans that are not too flexibly mounted. It also covers those pumps which are not dealt with by ISO 10816-7.

Significant differences in design, type of bearings and type of support structures require a division in ISO 10816-3 into two machinery groups, namely:

a) group 1: large machines with rated power above 300 kW or electrical machines with shaft heights equal to or above 315 mm;

b) group 2: medium-sized machines with a rated power above 15 kW up to and including 300 kW or electrical machines with shaft heights from 160 mm up to less than 315 mm.

The larger machines normally have sleeve bearings and the range of operating or nominal rotational speeds is relatively broad, ranging from 120 r/min to 15 000 r/min.

Classifications of the vibration severity zones for large industrial machines with rated power from 300 kW to 50 MW (group 1) are included. Classifications of the vibration severity zones for medium-sized industrial machines with rated power from 15 kW to 300 kW (group 2) are also included. The zone descriptions are the same as in ISO 10816-1.

5.4 ISO 10816-4 provides specific guidance for assessing the severity of vibration measured on the bearing housings or pedestals of gas turbine sets with fluid-film bearings.

ISO 10816-4 applies to heavy-duty gas turbines used in electrical and mechanical drive applications covering the power range above 3 MW and a rotational speed range under load between 3 000 r/min and 30 000 r/min. Generally, the criteria apply to both the gas turbine and the driven equipment. For generators above 50 MW, the criteria of ISO 10816-2 are used for assessing the vibration severity and ISO 10816-3 for generators rated up to and including 50 MW.

The evaluation of zone boundaries based on bearing housing or pedestal vibration for industrial gas turbines is included. These criteria assume that the gas turbines incorporate fluid-film bearings and the vibration measurements are broadband values taken *in situ* under normal steady-state operating conditions. Transient operating conditions, such as load changes and rotational speed changes, are also covered. ISO 10816-4 encompasses machines which may have gears, but does not address the evaluation of the condition of those gears. The zone descriptions are the same as in ISO 10816-1.

5.5 ISO 10816-5 provides specific guidance for assessing the severity of vibration measured on bearings, bearing pedestals or housings of hydraulic machines when measured *in situ*. ISO 10816-5 applies to machine sets in hydraulic power generation and pumping plants where the hydraulic machines have rotational speeds from 120 r/min to 1 800 r/min, shell or shoe type sleeve bearings and main engine power of 1 MW or more. The position of the shaft line may be vertical, horizontal or at an arbitrary angle between these two directions.

ISO 10816-5 includes: turbines and generators, pumps and electrical machines operating as motors, pump-turbines and motor generators, including auxiliary equipment (e.g. starting turbines or exciters in line with the main shaft). ISO 10816-5 also includes single turbines or pumps connected to generators or electric motors through gears and/or flexible couplings.

Recommended r.m.s. vibration criteria as a function of shaft rotational speed for hydraulic machines with nominal power above 1 MW and nominal rotational speeds between 120 r/min and 1 800 r/min are included.

© ISO 2013 – All rights reserved
Documents
Document Sharing Hub
Full document details: PD ISO/TR 19201:2013