INTERNATIONAL STANDARD

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Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 4: Gas turbine sets with fluid-film bearings

Vibrations mécaniques — Évaluation des vibrations des machines par mesurages sur les parties non tournantes —
Partie 4: Turbines à gaz à paliers à film fluide

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 10816-4 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 cancels and replaces the first edition (ISO 10816-4:1998), of which it constitutes a technical revision. The main changes are:

— clarification that the document applies only to gas turbine sets with fluid-film bearings;

— emphasis on acceptance specifications always being agreed on between the supplier and the purchaser of the gas turbine set prior to installation;

— the addition of provisions for evaluating the vibration of coupled gas turbine sets during transient operation;

— introduction of a new annex providing cautionary notes about the use of constant vibration velocity criteria at low frequencies;

— closer alignment of this part of ISO 10816 with ISO 7919-2, ISO 7919-4 and ISO 10816-2.

ISO 10816 consists of the following parts, under the general title *Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts*:

— *Part 1: General guidelines*

— *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*

— *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

— *Part 4: Gas turbine sets with fluid-film bearings*

— *Part 5: Machine sets in hydraulic power generating and pumping plants*

— *Part 6: Reciprocating machines with power ratings above 100 kW*

— *Part 7: Rotodynamic pumps for industrial applications, including measurements on rotating shafts*

Introduction

ISO 10816-1 is the basic part of ISO 10816 giving the general requirements for evaluating the vibration of various machine types when the vibration measurements are made on non-rotating parts. This part of ISO 10816 gives specific provisions for assessing the severity of vibration measured on the bearing housings or pedestals of gas turbine sets. Measurements at these locations characterize the state of vibration reasonably well. Evaluation criteria, based on previous experience, are presented. These can be used for assessing the vibratory condition of such machines.

Two criteria are provided for assessing the machine vibration when operating under steady-state conditions. One criterion considers the magnitude of the observed vibration; the second considers changes in the magnitude. In addition, different criteria are provided for transient operating conditions. However, vibration on non-rotating parts does not form the only basis for judging the severity of vibration. For gas turbine sets, it is also common to judge the vibration based on measurements taken on the rotating shafts. For shaft vibration measurement requirements, see ISO 7919-1 and ISO 7919-4.

The evaluation procedures presented in this part of ISO 10816 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 part of ISO 10816. They are dealt with in greater detail in ISO 13373 (all parts), which establish provisions for the vibration condition monitoring of machines.

Mechanical vibration — Evaluation of machine vibration by measurements on non-rotating parts —

Part 4: Gas turbine sets with fluid-film bearings

1 Scope

This part of ISO 10816 establishes provisions for evaluating the severity of *in-situ*, broad-band vibration measured radial (i.e. transverse) to the shaft axis on all main bearing housings or pedestals and in the axial direction on thrust bearings. These are in terms of:

— vibration under normal steady-state operating conditions;

— vibration during other (non-steady-state) conditions when transient changes are taking place, including run up or run down, initial loading and load changes;

— changes in vibration which can occur during normal steady-state operation.

This part of ISO 10816 is applicable to heavy-duty gas turbine sets used in electrical and mechanical drive applications, with fluid-film bearings, outputs greater than 3 MW and an operating speed range under load between 3 000 r/min and 30 000 r/min. This includes gas turbines coupled to other rotating machinery either directly or through a gearbox. In some cases, this part of ISO 10816 is not applicable to the evaluation of the vibration of the coupled equipment (see the list of exclusions in this clause).

EXAMPLE For single-shaft combined-cycle power units in which a gas turbine is coupled to a steam turbine and/or generator, the evaluation of the gas turbine vibration is according to this part of ISO 10816, but that of the steam turbine and generator is according to ISO 10816-2 or ISO 10816-3.

This part of ISO 10816 is not applicable to the following:

a) aero-derivative gas turbines (including gas turbines with dynamic properties similar to those of aero-derivatives);

   NOTE ISO 3977-3 defines aero-derivatives as aircraft propulsion gas generators adapted to drive mechanical, electrical or marine propulsion equipment. Large differences exist between heavy-duty and aero-derivative gas turbines, for example in casing flexibility, bearing design, rotor to stator mass ratio and mounting structure. Different criteria therefore apply for these two turbine types.

b) gas turbines with outputs less than or equal to 3 MW (see ISO 10816-3);

c) gas turbine driven pumps (see ISO 10816-7);

d) coupled steam turbines and/or generators with outputs less than or equal to 50 MW (see ISO 10816-3);

e) coupled steam turbines and/or generators with outputs greater than 50 MW (see ISO 10816-2);

f) synchronizing clutches which couple the gas turbine to a steam turbine or generator (see ISO 10816-2);

g) coupled compressors (see ISO 10816-3);

h) gearbox vibration (see this clause);

i) rolling element bearing vibration.

This part of ISO 10816 is applicable to other driven equipment not included in this list of exclusions.

This part of ISO 10816 is applicable to machines which can be coupled to a gearbox, but does not address the evaluation of the vibration condition of those gears. Specialist techniques are required for evaluating the vibration condition of gears which are outside the scope of this part of ISO 10816.

The numerical values specified are not intended to serve as the only basis for judging the severity of vibration. For gas turbine sets, it is also common to judge the vibration based on measurements taken on the rotating shafts. For such vibration measurement requirements, see ISO 7919-1 and ISO 7919-4.

2 Normative references

The following referenced documents are indispensable for the application 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 7919-4, *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts — Part 4: Gas turbine sets with fluid-film bearings*

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

3 Measurement procedures

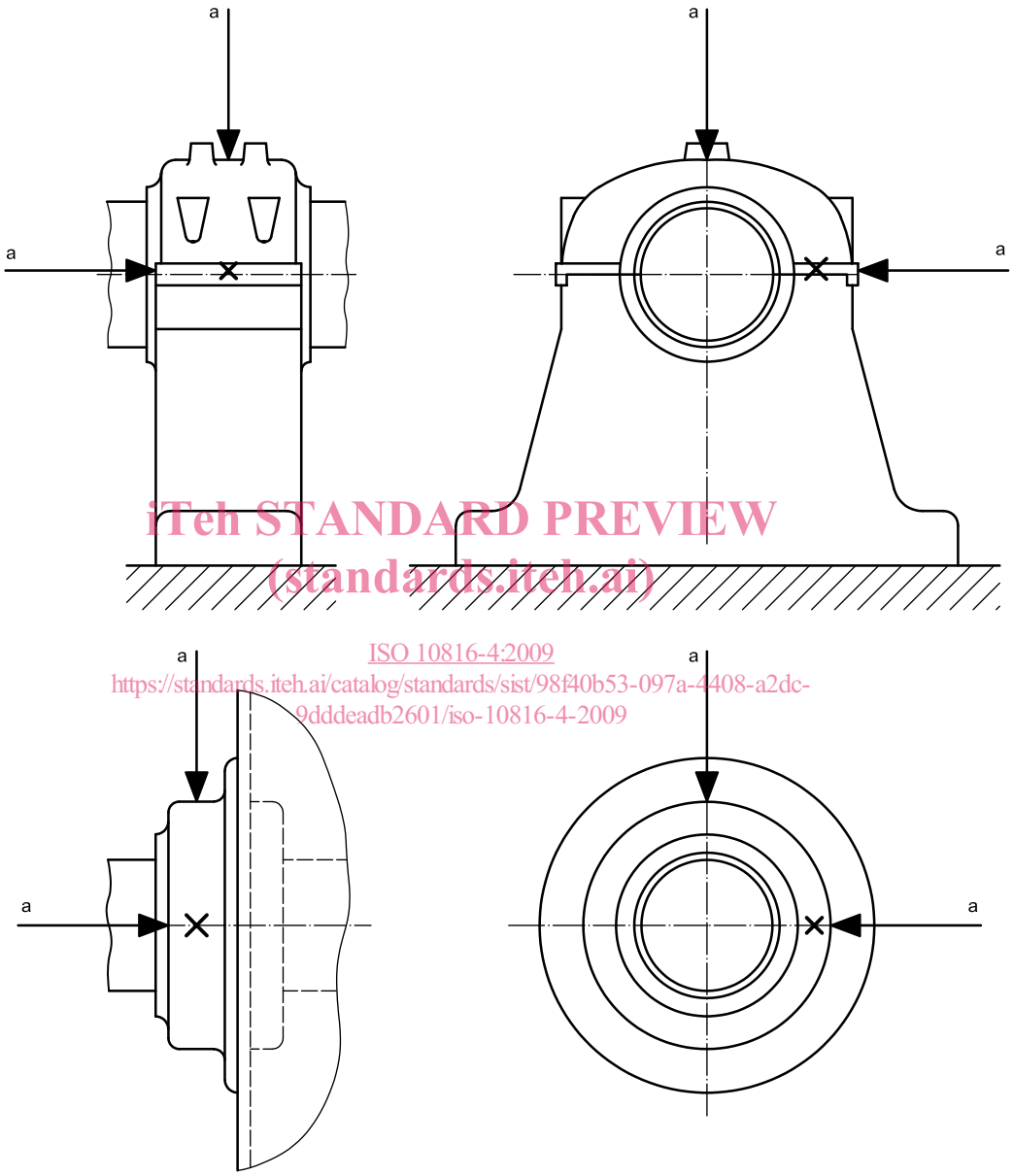
The measurement procedures and instrumentation shall comply with the general requirements of ISO 10816-1 and are as follows.

For monitoring purposes, the measurement system shall be capable of measuring broad-band vibration over a frequency range from 10 Hz to at least 500 Hz or six times the maximum normal operating frequency, whichever is the greater. If, however, the instrumentation is also used for diagnostic purposes, a wider frequency range and/or spectral analysis can be necessary. For example, in cases where the frequency corresponding to the first critical speed of the gas turbine is below 10 Hz, the lower limit of the linear range of the measurement system shall be reduced accordingly. In special cases where significant low-frequency vibration can be transmitted to the machine, such as in earthquake regions, it can be necessary to filter the low-frequency response of the instrumentation and/or implement an appropriate time delay. If measurements from different machines are compared, care should be taken to ensure that the same frequency range is used.

The locations of vibration measurements should be such that they provide adequate sensitivity to the dynamic forces of the machine. Care should be taken to ensure that the measurement equipment is not unduly influenced by external sources, such as combustion vibration, gear mesh vibration, and airborne and structure-borne noise. Typically, this requires measuring in two radial directions on each main bearing cap or pedestal with a pair of orthogonal transducers, as shown in Figures 1 and 2. The transducers may be placed at any angular location on the bearing housings or pedestals, although vertical and horizontal directions are usually preferred.

A single radial transducer may be used on a bearing cap or pedestal in place of the more typical pair of orthogonal transducers if it is known to provide adequate information on the magnitude of the machine vibration. In general, however, caution should be observed when evaluating vibration from a single transducer at a measurement plane since it might not be oriented to provide a reasonable approximation of the maximum value at that plane.

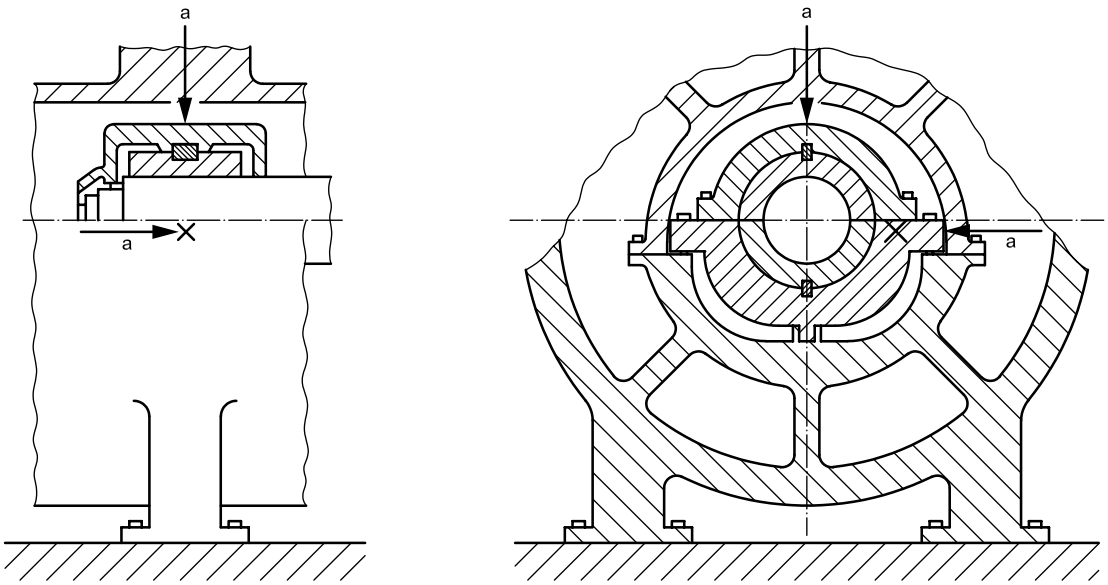
It is not common practice to measure axial vibration on the main radial load carrying bearings of gas turbines for continuous operational monitoring. Such measurements are primarily used during periodic vibration surveys or for diagnostic purposes. Hence, in this part of ISO 10816, axial vibration criteria are only provided for thrust bearings where the vibration severity can be judged using the same criteria as for radial vibration (see Table A.1). For other bearings where there are no axial restraints, a less stringent requirement may be used for the evaluation of axial vibration.



NOTE The evaluation criteria in this part of ISO 10816 are applicable to radial vibration on all main bearings and to axial vibration on thrust bearings.

[a] Direction of measurement.

Figure 1 — Typical measuring points and directions on bearing pedestals and bearing caps



NOTE The evaluation criteria in this part of ISO 10816 are applicable to radial vibration on all main bearings and to axial vibration on thrust bearings.

[a] Direction of measurement.

Figure 2 — Typical measuring points and directions on a gas turbine bearing

The characteristics of the measurement system should be known with regard to the effects of the environment, including:

a) temperature variations;

b) magnetic fields;

c) airborne and structure-borne noise;

d) power source variations;

e) cable impedance;

f) transducer cable length;

g) transducer orientation;

h) stiffness of the transducer attachment.

Particular attention should be given to ensuring that the vibration transducers are correctly mounted and that the mounting arrangement does not degrade the accuracy of the measurement (see for example ISO 2954 and ISO 5348).

4 Evaluation criteria

4.1 General

ISO 10816-1 provides a general description of the two evaluation criteria used to assess the vibration severity on various classes of machines. One criterion considers the magnitude of the observed broad-band vibration; the second criterion considers changes in magnitude, irrespective of whether they are increases or decreases.

The maximum magnitude of vibration measured is defined as the vibration severity. The values presented are the result of experience with machinery of this type and, if due regard is paid to them, acceptable operation can be expected.

NOTE These values are based on previous International Standards, on the results of a survey which was carried out when ISO 7919 (all parts) and ISO 10816 (all parts) were initially developed and on the feedback provided by the experts of ISO/TC 108.

Criteria are presented for steady-state operating conditions at the specified normal operating speed (or speeds) and load ranges, including normal slow changes in power output. Alternative criteria are also presented for other non-steady-state conditions when transient changes are taking place. The vibration criteria represent target values which give provisions for ensuring that gross deficiencies or unrealistic requirements are avoided. They serve as a basis for defining acceptance specifications (see 4.2.2.3).

The criteria relate to the vibration produced by the gas turbine set and not to vibration transmitted from outside the machinery set. If it is suspected that there is a significant influence due to transmitted vibration (either steady-state or intermittent), measurements should be taken with the gas turbine set shut down. If the magnitude of the transmitted vibration is unacceptable, steps should be taken to remedy the situation.

It should be noted that an overall judgement of the vibratory state of a machine is often made on the basis of measurements made on both non-rotating parts and rotating shafts.

4.2 Criterion I: Vibration magnitude

4.2.1 General

This criterion is concerned with defining values for absolute vibration magnitude consistent with acceptable dynamic loads on the bearings and acceptable vibration transmission into the support structure and foundation.

4.2.2 Vibration magnitude at normal operating speeds under steady-state operating conditions

4.2.2.1 General

The maximum vibration magnitude observed at each bearing or pedestal is assessed against four evaluation zones established from international experience.

4.2.2.2 Evaluation zones

The following evaluation zones are defined to permit an assessment of the vibration of a given machine under steady-state conditions at normal operating speed (or speeds) and to provide guidelines on possible actions.

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.

NOTE For transient operation, see 4.2.4.