INTERNATIONAL STANDARD

ISO 7919-4

First edition
1996-07-15

Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria —

Part 4:
Gas turbine sets

Vibrations mécaniques des machines non alternatives — Mesurages sur les arbres tournants et critères d'évaluation —

Partie 4: Turbines à gaz

Reference number
ISO 7919-4:1996(E)

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.

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.

International Standard ISO 7919-4 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

ISO 7919 consists of the following parts, under the general title *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria*:

— *Part 1: General guidelines*

— *Part 2: Large land-based steam turbine generator sets*

— *Part 3: Coupled industrial machines*

— *Part 4: Gas turbine sets*

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

Annex A forms an integral part of this part of ISO 7919.

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

Introduction

This part of ISO 7919 deals with the special features required for measuring transverse shaft vibration on the coupled rotor systems of gas turbine sets. Evaluation criteria, based on previous experience, are presented which may be used as guidelines for assessing the vibratory conditions of such machines.

A general description of the principles which are generally applicable for the measurement and evaluation of shaft vibration of non-reciprocating machines is given in ISO 7919-1.

Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria —

Part 4:
Gas turbine sets

1 Scope

This part of ISO 7919 gives guidelines for applying evaluation criteria for shaft vibration under normal operating conditions, measured at or close to the bearings of gas turbine sets. These guidelines are presented in terms of both steady running vibration and any magnitude changes which may occur in these steady values. The numerical values specified are not intended to serve as the only basis for vibration evaluation since, in general, the vibratory condition of a machine is assessed by consideration of both the shaft vibration and the associated structural vibration (see the introduction to ISO 7919-1).

This part of ISO 7919 applies to all gas turbine sets (including those with gears) with fluid-film bearings, outputs greater than 3 MW and shaft rotational frequencies from 3 000 r/min to 30 000 r/min. Aircraft derivative engines are excluded, since they differ fundamentally from industrial gas turbine sets, both in the type of bearings (rolling element bearings) and in the stiffness and mass ratios of the rotor and support structure. Depending on the construction and mode of operation, there are three principle groupings of gas turbine sets:

— single-shaft constant-speed gas turbine sets;

— single-shaft variable-speed gas turbine sets;

— gas turbine sets with separate shafts for hot gas generation and power delivery.

NOTE 1 Initially these three groups will be assessed in a uniform manner. It is possible, however, that individual cases will have to be assessed differently.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 7919. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 7919 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7919-1:1996, *Mechanical vibration of non-reciprocating machines — Measurements on rotating shafts and evaluation criteria — Part 1: General guidelines.*

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 to be followed and the instrumentation used shall be as described in ISO 7919-1.

In gas turbine sets, shaft vibration relative to the bearing is normally measured. Therefore, unless stated otherwise, the vibration displacements referred to in this part of ISO 7919 conform to this convention. In view of the relatively high rotational frequencies involved with gas turbine sets, measuring methods using non-contacting transducers are most common and are generally preferred on rotor elements with operating frequencies of 3 000 r/min and above. For monitoring purposes, the measuring system shall be capable of covering overall vibration up to a frequency equivalent to 2,5 times the maximum service speed. However, it should be noted that for diagnostic purposes it may be desirable to cover a wider frequency range.

4 Evaluation criteria

Criteria for vibration magnitude, changes in vibration magnitude and operational limits are presented in annex A.

The vibration magnitude is the higher value of the peak-to-peak displacement measured in two selected orthogonal measurement directions. The values presented are the result of experience with machinery of this type and, if due regard is paid to them, acceptable operation may be expected. If only one measuring direction is used, care should be taken to ensure that it provides adequate information (see ISO 7919-1).

The criteria are presented for the specified steady-state operating conditions at the rated speed and load ranges. They apply for normal slow changes in load but do not apply when different conditions exist or during transient changes, for example during start-up and shut-down and when passing through resonance ranges. In these cases alternative criteria are necessary.

It should be noted that an overall judgement of the vibratory state of a machine is often made on the basis of both relative shaft vibration as defined above and of measurements made on non-rotating parts (see ISO 10816-1).

Annex A
(normative)

Evaluation criteria for relative shaft vibration of gas turbine sets under specified operating conditions

A.1 General

Two evaluation criteria are used to assess the relative shaft vibration of gas turbine sets, measured at or close to the bearings. One criterion considers the magnitude of the observed broad-band relative shaft vibration; the second considers changes in magnitude, irrespective of whether they are increases or decreases.

A.2 Criterion I: Vibration magnitude at rated speed under steady operating conditions

This criterion is concerned with defining limits for shaft vibration magnitude consistent with acceptable dynamic loads on the bearing, adequate margins on the radial clearance envelope of the machine, and acceptable vibration transmission into the support structure and foundation. The maximum shaft vibration magnitude observed at each bearing is assessed against four evaluation zones established from international experience.

A.2.1 Evaluation zones

The following typical evaluation zones are defined to permit a qualitative assessment of the shaft vibration on a given machine and provide guidelines on possible actions.

Zone A The vibration of newly commissioned machines would normally fall 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.

A.2.2 Evaluation zone limits

In accordance with present accumulated experience of shaft vibration measurements in this field, the recommended values for the zone boundaries are inversely proportional to the square root of the shaft rotational frequency n (in revolutions per minute). The recommended values presented in figure A.1 are derived from the expressions below:

Zone boundary A/B

$$S_{(p\text{-}p)} = 4\,800/\sqrt{n}\ \mu\text{m}$$

Zone boundary B/C

$$S_{(p\text{-}p)} = 9\,000/\sqrt{n}\ \mu\text{m}$$

Zone boundary C/D

$$S_{(p\text{-}p)} = 13\,200/\sqrt{n}\ \mu\text{m}$$

NOTE 2 For a definition of $S_{(p\text{-}p)}$, see ISO 7919-1.

These values are not intended to serve as acceptance specifications, which shall be subject to agreement between the machine manufacturer and customer. However, they provide guidelines for ensuring that gross deficiencies or unrealistic requirements are avoided.

In certain cases, there may be specific features associated with a particular machine which would require different zone boundary values (higher or lower) to be used. For example, with a tilting pad bearing it may be necessary to specify alternative vibration values, whilst in the case of an elliptical bearing, different vibration criteria may apply for the directions of maximum and minimum bearing clearances. In particular, it should be recognised that the allowable vibration may be related to the journal diameter since, generally, running clearances will be greater for larger diameter bearings. Consequently different values may apply for measurements taken at different bearings on the same rotor line. In such cases, it is normally necessary to explain the reasons for this and, in particular, to confirm that the machine will not be endangered by operating with higher vibration values.

Higher values of vibration can be permitted at other measuring positions and under transient conditions, such as start-up and run-down (including passage through critical speed ranges).

A.3 Criterion II: Change in vibration magnitude

This criterion provides an assessment of a change in vibration magnitude from a previously established reference or baseline value. A significant increase or decrease in shaft vibration magnitude may occur which requires some action even though zone C of Criterion I has not been reached. Such changes can be instantaneous or progressive with time and may indicate that damage has occurred or be a warning of an impending failure or some other irregularity. Criterion II is specified on the basis of the change in shaft vibration magnitude occurring under steady-state operating conditions.

The reference value for this criterion is the typical, reproducible normal vibration, known from previous measurements for the specific operating conditions. If this reference value changes by a significant amount, and certainly if it exceeds 25 % of the upper limiting value for zone B, regardless of whether this increases or decreases the magnitude of vibration, steps should be taken to ascertain the reasons for the change. A decision on what action to take, if any, should then be made after consideration of the maximum value of vibration and whether the machine has stabilized at a new condition.

When Criterion II is applied, the vibration measurements being compared shall be taken at the same transducer location and orientation, and under approximately the same machine operating conditions.

It is necessary to appreciate that a criterion based on change of vibration has limited application, since significant changes of varying magnitude and rates can and do occur in individual frequency components, but the importance of these is not necessarily reflected in the broad-band shaft vibration signal (see ISO 7919-1). For example, the propagation of a crack in a rotor may introduce a progressive change in vibration components at multiples of rotational frequency, but their magnitude may be small relative to the amplitude of the once-per-revolution rotational frequency component. Consequently, it may be difficult to identify the effects of the crack propagation by looking at the change in the broad-band vibration only. Therefore, although monitoring the change in broad-band vibration will give some indication of potential problems, it may be necessary in certain applications to use measuring and analysis equipment which is capable of determining the trends of the vector changes that occur in individual frequency components of the vibration signal. This equipment may be more sophisticated than that used for normal supervisory monitoring and its use and application requires specialist knowledge. Hence, the specification of detail criteria for measurements of this type is beyond the scope of this part of ISO 7919.

A.4 Operational limits

For long-term operation it is common practice to establish operational vibration limits. These limits take the form of ALARMS and TRIPS.

ALARMS: To provide a warning that a defined value of vibration has been reached or a significant change has occurred, at which remedial action may be necessary. In general, if an ALARM situation occurs, operation can continue for a period whilst investigations are carried out to identify the reason for the change in vibration and define any remedial action.

TRIPS: To specify the magnitude of vibration beyond which further operation of the machine may cause damage. If the TRIP value is exceeded, immediate action should be taken to reduce the vibration or the machine should be shut down.

Different operational limits, reflecting differences in dynamic loading and support stiffness, may be specified for different measurement positions and directions.

A.4.1 Setting of ALARMS

The ALARM values may vary considerably, up or down, for different machines. The values chosen will normally be set relative to a baseline value determined from experience for the measurement position or direction for that particular machine.

It is recommended that the ALARM value should be set higher than the baseline by an amount equal to 25 % of the upper limit of zone B. If the baseline is low, the ALARM may be below zone C.

Where there is no established baseline, for example with a new machine, the initial ALARM setting should be based either on experience with other similar machines or relative to agreed acceptance values. After a period of time, the steady-state baseline value will be established and the ALARM setting should be adjusted accordingly.

If the steady-state baseline changes (for example after a machine overhaul), the ALARM setting should be revised accordingly. Different operational ALARM settings may then exist for different bearings on the machine, reflecting differences in dynamic loading and bearing support stiffnesses.

A.4.2 Setting of TRIPS

The TRIP values will generally relate to the mechanical integrity of the machine and be dependent on any specific design features which have been introduced to enable the machine to withstand abnormal dynamic forces. The values used will, therefore, generally be the same for all machines of similar design and would not normally be related to the steady-state baseline value used for setting ALARMS.

There may, however, be differences for machines of different design and it is not possible to give more precise guidelines for absolute TRIP values. In general, the TRIP value will be within zone C or D.

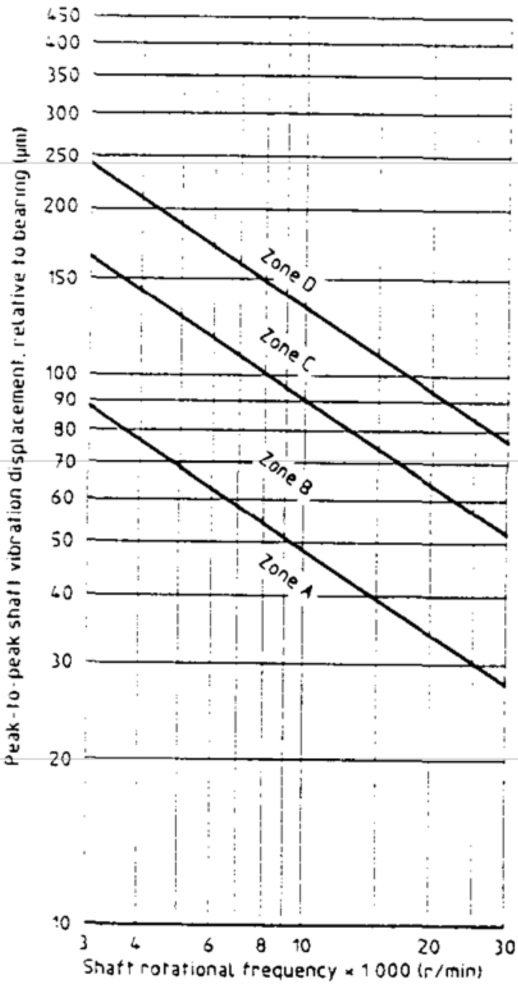

Figure A.1 — Recommended values for maximum relative displacement of the shaft as a function of the maximum service speed for gas turbine sets