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Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts —

Part 3: Coupled industrial machines

Vibrations mécaniques — Évaluation des vibrations des machines par mesurages sur les arbres tournants —
Partie 3: Machines industrielles couplées

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Foreword

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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 7919-3 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 7919-3:1996), of which it constitutes a minor revision. It also incorporates the Technical Corrigendum ISO 7919-3:1996/Cor.1:2007.

ISO 7919 consists of the following parts, under the general title *Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts*:

— *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: Coupled industrial machines*

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

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

Introduction

This part of ISO 7919 specifies guidelines for measuring transverse shaft vibration on coupled industrial machines. Evaluation criteria, based on previous experience, are given for use as guidelines for assessing the vibratory conditions of such machines.

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

Mechanical vibration — Evaluation of machine vibration by measurements on rotating shafts —

Part 3: Coupled industrial machines

1 Scope

This part of ISO 7919 gives guidelines for applying evaluation criteria of shaft vibration under normal operating conditions, measured at or close to the bearings of coupled industrial machines. These guidelines are presented in terms of both steady running vibration and any amplitude changes which can 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.

This part of ISO 7919 applies to coupled industrial machines with fluid-film bearings, having maximum continuous rated speeds in the range 1 000 r/min to 30 000 r/min and not limited by size and power, comprising

— steam turbines,

— turbocompressors,

— turbogenerators,

— turbofans,

— electric drives and associated gears, where relevant, and

— rotodynamic pumps (turbo pumps).

The information relating to pumps provided in this part of ISO 7919 complements that given in ISO 10816-7. In particular, the conditions for *in-situ* operation, performing acceptance tests and the influence of bearing clearance given in ISO 10816-7 shall be taken into account when evaluating the shaft vibration of pumps

This part of ISO 7919 is neither applicable to land-based steam turbine-generator sets for power stations with outputs greater than 50 MW (see ISO 7919-2), nor machine sets in hydraulic power generating and pumping plants with outputs of 1 MW or greater (see ISO 7919-5).

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

3 Measurement procedures

The measurement procedures to be followed and the instrumentation which shall be used are specified in ISO 7919-1.

In industrial machines, shaft vibration relative to the bearing is normally measured. Therefore, unless stated otherwise, this part of ISO 7919 always refers to relative vibration displacement. In view of the relatively high rotational speeds involved with industrial machines, measuring methods using non-contacting transducers are most common and are generally preferred on rotor elements with operating speeds 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 might be desirable to cover a wider frequency range.

4 Evaluation criteria

The criteria for vibration magnitude, changes in vibration magnitude and operational limits are given 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 can 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 overall judgement of the vibratory state of a machine is often made on the basis of both shaft relative vibration as defined above and of measurements made on non-rotating parts (see ISO 10816-3)[2].

Annex A
(normative)

Evaluation criteria for relative shaft vibration of coupled industrial machines under specified operating conditions

A.1 General

Two evaluation criteria are used to assess the relative shaft vibration of coupled industrial machines, 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.

Caution should be exercised when using the criteria presented in Annex A to ensure that no contact occurs between the rotating shaft and stationary parts. Therefore, in certain cases the shaft displacement limits given in this part of ISO 7919 may exceed the available clearance. In such cases the evaluation zone limits should be adjusted accordingly.

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 bearings, 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 of a given machine 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.

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 maximum operating speed of the shaft, n (in revolutions per minute). The recommended values illustrated in Figure A.1 are derived from Equation (A.1), Equation (A.2) and Equation (A.3):

Zone A/B boundary limit, in micrometres

$$S_{(p-p)} = 4\,800 \Big/ \sqrt{n}\ \mu m \tag{A.1}$$

Zone B/C boundary limit, in micrometres

$$S_{(p-p)} = 9\,000 \Big/ \sqrt{n}\ \mu m \tag{A.2}$$

Zone C/D boundary limit, in micrometres

$$S_{(p-p)} = 13\,200 \Big/ \sqrt{n}\ \mu m \tag{A.3}$$

NOTE For a definition of $S_{(p-p)}$, 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 the customer. However, they provide guidelines for ensuring that gross deficiencies or unrealistic requirements are avoided.

In certain cases, there can be specific features associated with a particular machine, which would require different zone boundary values (lower or higher) to be used. For example, with a tilting pad bearing it might be necessary to specify alternative vibration values, whilst in the case of an elliptical bearing different vibration criteria can apply for the directions of maximum and minimum bearing clearance. In particular, it should be recognized that the allowable vibration can be related to the journal diameter since, generally, running clearances will be greater for larger diameter bearings. Consequently different values can 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 for particular steady-state conditions. A significant increase or decrease in shaft vibration magnitude can occur which would require some action even though zone C of Criterion I has not been reached. Such changes can be instantaneous or progressive with time and can 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 limit 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 can be taken, 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 vibration signal (see ISO 7919-1). For example, the propagation of a crack in a rotor can introduce a progressive change in vibration components at multiples of rotational frequency, but their magnitude might be small relative to the amplitude of the once-per-revolution rotational frequency component. Consequently, it can 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 might 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 can be more sophisticated than that used for normal supervisory monitoring and its use and application requires specialist knowledge. Hence, the specification of detailed criteria for measurements of this type is beyond the scope of this part of ISO 7919.

A.4 Operational limits

For many machines, mainly those of small size or power, continuous monitoring of vibration is not necessary. However, for those machines for which continuous monitoring of vibration is employed, 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 limit 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 limits may vary considerably for individual 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 limit be set higher than the baseline by an amount equal to 25 % of the zone boundary B/C. 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 limits 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.