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Industrial fans — Specifications for balance quality and vibration levels

Ventilateurs industriels — Spécifications pour l'équilibrage et les niveaux de vibration

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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 14694 was prepared by Technical Committee ISO/TC 117, *Industrial fans*.

Introduction

ISO 14694 is a part of a series of standards covering important aspects of fans which affect their design, manufacture and use. This series includes ISO 5801, ISO 5802, ISO 12499, ISO 13347, ISO 13348, ISO 13349, ISO 13350, ISO 13351, ISO 14695 and CEN/BTS 2/AH 17.

This International Standard addresses the needs of both users and manufacturers of fan equipment for a technically accurate but uncomplicated set of information on the subjects of balance precision and vibration levels.

Vibration is recognized as an important parameter in the description of the performance of fans. It gives an indication of how well the fan has been designed and constructed and can forewarn of possible operational problems. These problems may be associated with inadequacies of support structures and machine deterioration, etc.

Although alternative standards exist which deal with vibration of machines generally (e.g. ISO 10816), they currently have limitations because of their universal nature, when considering a specific family of machines such as fans, with installed powers below 300 kW.

Vibration measurements may therefore be required for a variety of reasons of which the following are the most important:

a) design/development evaluations;

b) in situ testing;

c) as information for a condition-monitoring or machinery health programme (ISO 14695:2003, Annex C gives recommended measuring positions for machinery health measurement);

d) to inform the designer of supporting structures, foundations, ducting systems, etc., of the residual vibration which will be transmitted by the fan into the structure;

e) as a quality assessment at the final inspection stage.

NOTE All the information which can be obtained from tests conducted in accordance with this International Standard (see Clause 10 of ISO 14695:2003) is neither necessary nor appropriate for quality-grading purposes.

Whilst an open inlet/open outlet test may be useful as a quality guide, this International Standard recognizes that the vibration of a fan will be dependent upon the aerodynamic duty specified, which determines the rotational speed and position on the fan.

This International Standard should be read in conjunction with ISO 10816-1, ISO 10816-3 and ISO 14695 which describe the methods to be used and the positions of the transducers. When information is required on vibration transmitted to ducting connections or foundations, then this is especially important. The gradings included are such as are generally recommended for commercially available fans.

It is important to remember that vibration testing can be extremely expensive, sometimes considerably in excess of the fan's initial cost. Only when the functioning of the installation may be affected should discrete frequency or band limitations be imposed. The number of test points should also be limited according to the usage envisaged. Readings at the fan bearings are of most importance and for normal quality gradings should be sufficient.

Industrial fans — Specifications for balance quality and vibration levels

1 Scope

This International Standard gives specifications for vibration and balance limits of fans for all applications except those designed solely for air circulation, for example, ceiling fans and table fans. However, it is limited to fans of all types installed with a power of less than 300 kW or to a commercially available standard electric motor with a maximum power of 355 kW (following an R20 series). For fans of greater power than this, the applicable limits are those given in ISO 10816-3. Where the fans in an installation have varying powers both above and below 300 kW, and have been the subject of a single contract, then the manufacturer and purchaser shall agree on the appropriate standard to be used. This should normally be based on the majority of units.

Vibration data may be required for a variety of purposes as detailed in Clause 5.

The International Standard recognizes that vibrational measurements may be recorded as velocity, acceleration or displacement either in absolute units or in decibels above a given reference level. The magnitude of vibration measurements may be affected by assembly practices at balancing machines (see Annex B). The preferred parameter is, however, the velocity, in millimeters per second (mm/s). As the conventions vary in different parts of the world, both r.m.s. (root mean square) and peak-to-peak or peak values are given. It should also be remembered that a fan and its parts may be considered as a spring-mass system. An understanding of this fact helps to resolve most vibrational problems (see Annex D).

Account has also been taken of the fact that factory tests are usually conducted with the fan unconnected to a ducting system, such that its aerodynamic duty may be considerably different from that during normal operation. It may also be supported on temporary foundations of different mass and stiffness to those used in situ. Accordingly, such tests are specified with vibration measured “filter-in”. In situ tests are specified “filter-out” and as such represent a measure of overall vibration severity.

This International Standard covers fan equipment with rigid rotors, generally found in: commercial heating, ventilating and air conditioning, industrial processes, mine/tunnel ventilation and power-generation applications. Other applications are not specifically excluded. Excluded are installations which involve severe forces, impacts or extreme temperatures. Any or all portions of this International Standard, or modifications thereof, are subject to agreement between the parties concerned.

Fan-equipment foundations and installation practices are beyond the scope of this International Standard. Foundation design and fan installation are not normally the responsibilities of the fan manufacturer. It is fully expected that the foundations upon which the fan is mounted will provide the support and stability necessary to meet the vibration criteria of the fan as it is delivered from the factory.

Other factors, such as impeller cleanliness, aerodynamic conditions, background vibration, operation at speeds other than those agreed upon, and maintenance of the fan, affect the fan-vibration levels but are beyond the scope of this International Standard.

This International Standard is intended to cover only the balance or vibration of the fan and does not take into account the effect of fan vibration on personnel, equipment or processes.

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 254, *Belt drives — Pulleys — Quality, finish and balance*

ISO 1940-1:1986, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual unbalance*

ISO 1940-1:—[1], *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Specification and verification of balance tolerances*

ISO 4863:1984*, Resilient shaft couplings — Information to be supplied by users and manufacturers*

ISO 5348:1998, *Mechanical vibration and shock — Mechanical mounting of accelerometers*

ISO 5801:1997, *Industrial Fans — Performance testing using standardized airways*

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

ISO 10816-3:1998, *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 13348:—[2], *Industrial fans — Specification of technical data and verification of performance*

ISO 14695:2003, *Industrial fans — Method of measurement of fan vibration*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
vibration severity
generic term that designates a value, or set of values, such as a maximum value, average or r.m.s. value, or other parameter that is descriptive of the vibration

NOTE 1 The vibration severity may refer to instantaneous values or to average values.

NOTE 2 Adapted from ISO 2041:1990, definition 2.42.

3.2
axis of rotation
instantaneous line about which a body rotates

NOTE 1 If the bearing are anisotropic, there is no stationary axis of rotation.

NOTE 2 In the case of rigid bearings, the axis of rotation is the shaft axis, but if the bearings are not rigid, this axis of rotation is not necessarily the shaft axis.

NOTE 3 Adapted from ISO 1925:2001, definition 1.4.

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1) To be published. (Revision of ISO 1940-1:1986)

2) To be published.

3.3
balancing
procedure by which the mass distribution of a rotor is checked and, if necessary, adjusted to ensure that the residual unbalance or the vibration of the journals and/or forces on the bearings at a frequency corresponding to service speed are within specified limits

NOTE 1 Balancing of fan impellers is achieved by the process of adding (or removing) weight in a plane or planes on the impeller in order to move the centre of gravity towards the axis of rotation. This will reduce the unbalance forces.

NOTE 2 Adapted from ISO 1925:2001, definition 4.1.

3.4
balance quality grade
⟨rigid rotors⟩ measure for classification which is the product of the specific unbalance and the maximum service angular velocity of the rotor, expressed in millimetres per second

NOTE 1 Commonly used grades in ISO 1940-1 refer to the vibration that would result if that rotor operated in free space i.e. balance grade 6,3 corresponds to a shaft vibration of 6,3 mm/s, peak velocity, at the operating speed of the rotor.

NOTE 2 Adapted from ISO 1925:2001, definition 3.16.

3.5
displacement
relative displacement
vector quantity that specifies the change of position of a body, or particle, with respect to a reference frame

NOTE 1 The reference frame is usually a set of axes at a mean position or a position of rest. In general, the velocity can be represented by a rotation vector, a translation vector, or both.

NOTE 2 A displacement is designated as relative displacement if it is measured with respect to a reference frame other than the primary reference frame designated in the given case. The relative displacement between two points is the vector difference between the displacements of the two points.

NOTE 3 Adapted from ISO 2041:1990, definition 1.1.

3.6
displacement measurements
vibration values that describe the motion of the rotating-shaft surface relative to the static bearing housing

See ISO 7919-1.

3.7
electrical runout
certain errors which may be introduced into runout measurements when using non-contacting sensors

NOTE 1 Such errors may arise from residual magnetism or electrical inhomogeneity in the measured component or other effects which affect the calibration of the sensor.

NOTE 2 This total measured variation in the apparent location of a ferrous-shaft surface during a complete slow rotation is determined by an eddy-current probe system. This measurement may be affected by variations in the electrical/magnetic properties of the shaft material as well as variations in the shaft surface itself.

NOTE 3 Adapted from ISO 1925:2001, definition 2.19.

3.8
fan application category
descriptive grouping used to describe fan applications, their appropriate Balance Quality Grades and Recommended Vibration Levels

3.9
fan vibration level
vibration amplitude at the fan bearings expressed in units of velocity or displacement

3.10
filter
device for separating oscillations on the basis of their frequency

NOTE 1 It introduces relatively small attenuation to wave oscillations in one or more frequency bands and relatively large attenuation to oscillations of other frequencies.

NOTE 2 Adapted from ISO 2041:1990, definition B.14.

3.11
filter-In
sharp
vibration measured only at a frequency of interest

3.12
filter-out
broad pass
vibration measured in a wide frequency range

NOTE This is sometimes called “overall” vibration.

3.13
flexible support
fan support system designed so that the first natural frequency of the support is well below the operating speed of the fan

NOTE Often this involves compliant elastic elements between the fan and the supporting structure. This condition is achieved by suspending the machine on a spring or by mounting on an elastic support (springs, rubber, etc.). The natural oscillation frequency of the suspension and machine is typically less than 25 % of the frequency corresponding to the lowest speed of the machine under test.

3.14
foundation
structure that supports a mechanical system

NOTE 1 It may be fixed in a specified reference frame or it may undergo a motion that provides excitation for the supported system.

NOTE 2 For fans, these are the components on which the fan is mounted and which provide the necessary support. Fan foundations must have sufficient mass and rigidity to avoid vibration amplification.

NOTE 3 Adapted from ISO 2041:1990, definition 1.23.

3.15
frequency
cyclic frequency
the reciprocal of the fundamental period

NOTE 1 The unit of frequency is the Hertz (Hz) which corresponds to one cycle per second.

NOTE 2 In the fan industry, it is also common to use the number of cycles occurring per minute (CPM).

NOTE 3 Adapted from ISO 2041:1990, definition 2.24.

3.16
in situ
refers to operation at the final installation site

3.17
mechanical run-out
total actual variation in the location of a shaft surface during a complete slow rotation as determined by a stationary measuring device (such as a dial indicator)

3.18
journal
that part of a rotor which is supported radially and/or guided by a bearing in which it rotates

NOTE Adapted from ISO 1925:2001, definition 2.4.

3.19
overall fan vibration

See definition 3.12

3.20
peak value
peak magnitude
positive (negative) peak value
maximum value of a vibration during a given interval

NOTE 1 A peak-value vibration is usually taken as the maximum deviation of that vibration from the mean value. A positive peak value is the maximum positive deviation and a negative peak value is the maximum negative deviation.

NOTE 2 Peak displacement, velocity or acceleration readings refer to the value occurring at the maximum deviation from zero or the stationary value (see Annex A).

NOTE 3 Adapted from ISO 2041:1990, definition 2.34.

3.21
peak-to-peak value (of a vibration)
⟨vibration⟩ algebraic difference between the extreme values of the vibration

NOTE 1 In industrial practice, peak-to-peak amplitudes refer to the total range travelled in one cycle. Peak-to-peak readings apply to displacements only (see Annex A).

NOTE 2 Adapted from ISO 2041:1990, definition 2.35.

3.22
root-mean-square value
r.m.s. value
⟨set of numbers⟩ square root of the average of their squared values

NOTE 1 The r.m.s. value of a set of numbers can be represented as follows:

$$\text{r.m.s.value} = \left(\frac{\sum_n x_n^2}{N} \right)^{1/2}$$

where the subscript n refers to the n^{th} number, of which there are a total of N.

⟨single-valued function, $f(t)$, over an interval between t_1 and t_2⟩ square root of the average of the squared values of the function over the interval

NOTE 2 The r.m.s. value of a single-valued function, $f(t)$, over an interval between equal to t_1 and t_2 is equal to

$$\text{r.m.s.value} = \left(\frac{\int_{t_1}^{t_2} f(t)^2 \mathrm{d}t}{t_2 - t_1} \right)^{1/2}$$

NOTE 3 In vibration theory, the mean value of the vibration is equal to zero. In this case, the r.m.s. value is equal to the standard deviation, and the mean-square value is equal to the variance (σ^2).

NOTE 4 For true sinusoidal motion the r.m.s. value is equal to 0,707 times the peak value.

NOTE 5 Adapted from ISO 2041:1990, definition A.37.

3.23
residual unbalance
final unbalance
unbalance of any kind that remains after balancing

NOTE Adapted from ISO 1925:2001, definition 3.10.

3.24
rigid support
fan support system designed so that the first natural frequency of the system is well above the operating speed of the fan

NOTE The rigidity of a foundation is a relative quantity. It must be considered in conjunction with the rigidity of the machine-bearing system. The ratio of bearing-housing vibration to foundation vibration is a characteristic quantity for the evaluation of foundation flexibility influences. A foundation may be rigid and of sufficient mass if the vibration amplitude of the foundation (in any direction) near the machine's feet or base frame is less than 25 % of the maximum amplitude that is measured at the adjacent bearing housing in any direction.

3.25
speed, design
maximum rotational speed, measured in revolutions per minute (r/min), for which the fan is designed to operate

3.26
speed, service
rotational speed, measured in revolutions per minute (r/min), for which a rotor operates in its final installation or environment

3.27
triaxial set
orientations of the vibration transducer for vibration-amplitude measurements

NOTE A triaxial set refers to a set of three readings taken in three mutually perpendicular (normally horizontal, vertical and axial) directions.

3.28
trim balancing
correction of small residual unbalances in a rotor, often *in situ*

NOTE 1 The balance process may make minor correction in unbalance which become necessary as a result of the fan assembly and/or installation process.

NOTE 2 Adapted from ISO 1925:2001, definition 4.27.

3.29
unbalance
condition which exists in a rotor when vibration force or motion is imparted to its bearings as a result of centrifugal forces

NOTE 1 The term unbalance is sometimes used as a synonym for amount of unbalance, or unbalance vector.

NOTE 2 The term imbalance is sometimes used in place of unbalance, but this is deprecated.

NOTE 3 Unbalance is usually measured by the product of the mass of the rotor times the distance between its centre of gravity and its centre of rotation in a plane. In general practice unbalance values are reported as

— peak-to-peak displacement, in micrometres (μm) or millimetres (mm);

— velocity — r.m.s. or peak, in millimetres per second (mm/s);

— acceleration — r.m.s. or peak, in metres per second squared (m/s^2).

NOTE 4 Adapted from ISO 1925:2001, definition 3.1.

3.30
velocity
relative velocity
vector that specifies the time-derivative of displacement

NOTE 1 The reference frame is usually a set of axes at a mean position or a position of rest. In general, the velocity can be represented by a rotation vector, a translation vector, or both.

NOTE 2 A velocity is designated as relative velocity if it is measured with respect to a reference frame other than the primary reference frame designated in a given case. The relative velocity between two points is the vector difference between the velocities of the two points.

NOTE 3 Adapted from ISO 2041:1990, definition 1.2.

3.31
vibration
variation with time of the magnitude of a quantity which is descriptive of the motion or position of a mechanical system, when the magnitude is alternately greater and smaller than some average value or reference

NOTE 1 Vibration may be thought of as the alternating mechanical motion of an elastic system, components of which are amplitude, frequency and phase. In general practice, vibration values are reported as:

— peak-to-peak displacement, in micrometres (μm) or millimetres (mm);

— velocity — r.m.s. or peak, in millimetres per second (mm/s);

— acceleration — r.m.s. or peak, in metres per second squared (m/s^2).

NOTE 2 Adapted from ISO 2041:1990, definition 2.1.

3.32
vibration spectrum
description of the vibration in terms of the amplitudes of its components versus frequency

3.33
vibration transducer
device designed to be attached to a mechanical system for measurement of vibration

NOTE It converts the vibratory energy into a proportional electronic signal that can be displayed or otherwise processed.

4 Symbols and units

For the purposes of this International Standard, the following symbols and units shall be used.