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Industrial fans — Method of measurement of fan vibration

Ventilateurs industriels — Méthode de mesure des vibrations des ventilateurs

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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 14695 was prepared by Technical Committee ISO/TC 117, *Industrial fans*.

Introduction

ISO 14695 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 13349, ISO 13350, ISO 13351 and ISO 14694.

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

Vibration measurements may 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 14694 and Annex C gives recommended measuring positions for machinery health measurement);

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

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

f) to be sure of acceptability of specific dynamic loading.

All the information which can be obtained from tests conducted in accordance with this International Standard (see Clause 10) is neither necessary nor appropriate for quality-grading purposes. Reference should be made to ISO 14694 for this purpose. Vibration as a consequence of unbalance should be measured at the fan bearings and, in this connection, the recommendations given in ISO 1940-1 should be followed.

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 specified aerodynamic duty, which determines the rotational speed and position on the far characteristic curve.

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

This International Standard describes the methods of measurement which will give consistent results and which may be used as a basis for comparison between products. The amount of information which needs to be presented and the preferred units are given in ISO 14694. Such information is dependent on the purpose for which the test has been conducted, the type of fan, its application and its method of mounting in service.

Industrial fans — Method of measurement of fan vibration

1 Scope

This International Standard describes a method of measuring the vibrational characteristics of fans of all types, 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. For fans of greater power than this, the methods described in ISO 10816-1 and the applicable limits given in ISO 10816-3 may be used. This International Standard gives a general method only and does not give criteria for interpretation of data (see ISO 14694).

This International Standard specifies the measurement of vibration that may be recorded as overall root-mean-square r.m.s. velocity, acceleration or displacement, or in terms of a frequency spectrum, within the appropriate frequency range. Methods of testing when suspended on elastic ropes or when installed on resilient mountings are included.

It is recognized that the oscillatory forces at mounting points can be a useful measurement for analysing the effects on support structures, but such measurements are outside the scope of this International Standard.

Annexes are given for information. Annex B gives secondary measurement methods which, whilst not recommended for accurate measurements, may be used for assessing the balance of series-produced fans or for comparative site measurements.

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

ISO 2041:1990, *Vibration and shock — Vocabulary*

ISO 2954, *Mechanical vibration of rotating and reciprocating machinery — Requirements for instruments for measuring vibration severity*

ISO 5801:1997, *Industrial fans — Performance testing using standardised airways*

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 14694:2003, *Industrial fans — Specification for balance quality and vibration levels*

IEC 60034-14, *Rotating electrical machines — Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher — Measurement, evaluation and limits of vibration*

IEC 60651, *Sound level meters*

IEC 61260, *Electroacoustics — Octave-band and fractional- octave band filters*

3 Terms and definitions

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

3.1
background vibration
all sources of vibration independent of the source

3.2
duty point
⟨aerodynamic duty⟩ point on the fan performance curve at which a fan operates

3.3
fan performance curve
⟨fan characteristic⟩ plot of pressure rise developed by the fan against the airflow through a fan

3.4
radius of gyration
measure of the distribution of mass about a chosen axis, given as the square root of the moment of inertia about that axis divided by the mass

3.5
resilient mount
mount with elastic characteristics, and measurable deflection, but no permanent deformation under normal load conditions

4 Symbols and units

For the purposes of this International Standard, the following symbols and units apply.

Symbol	Term	Unit
a	Instantaneous vibration acceleration	m/s^2
a_o	Reference vibration acceleration	m/s^2
A	Vibration acceleration amplitude of peak	m/s^2
A_{dB}	r.m.s. vibration acceleration level above a reference of 10^{-6} m/s^2 $A_{dB} = 20 \log_{10}\left(\frac{A_{r.m.s.}}{10^{-6}}\right)$	dB
$A_{r.m.s.}$	r.m.s. vibration-acceleration amplitude	m/s^2
d	Instantaneous vibration displacement	µm, mm or m
D	Vibration displacement amplitude of peak	µm, mm or m

Symbol	Term	Unit
f	Frequency = $\omega/2\pi$	Hz
f_H	Frequency of sway mode of vibration	Hz
f_R	Frequency of rotational mode of vibration in zx plane	Hz
f_T	Frequency of torsion/yaw mode of vibration in xy plane	Hz
f_V	Frequency of vertical mode of vibration	Hz
f_1	Frequency of coupled rocking mode where sway is dominant	Hz
f_2	Frequency of coupled rocking mode where rotation is dominant	Hz
I_R	Moment of inertia of system about y-axis through centre of gravity of system	kg·m^2
I_T	Moment of inertia of system about z-axis through centre of gravity of system located at X_G, Y_G, Z_G	kg·m^2
$I_{zz,1}$	Moment of inertia of fan about z-axis through centre of gravity of fan located at x_1, y_1, z_1	kg·m^2
$I_{zz,2}$	Moment of inertia of motor about z-axis through centre of gravity of motor located at x_2, y_2, z_2	kg·m^2
$I_{zz,3}$	Moment of inertia of base about z-axis through centre of gravity of base located at x_3, y_3, z_3	kg·m^2
$I_{xx,1}$	Moment of inertia of fan about x-axis through centre of gravity of fan located at x_1, y_1, z_1	kg·m^2
$I_{xx,2}$	Moment of inertia of motor about x-axis through centre of gravity of motor located at x_2, y_2, z_2	kg·m^2
$I_{xx,3}$	Moment of inertia of base about x-axis through centre of gravity of base located at x_3, y_3, z_3	kg·m^2
$I_{yy,1}$	Moment of inertia of fan about y-axis through centre of gravity of fan located at x_1, y_1, z_1	kg·m^2
$I_{yy,2}$	Moment of inertia of motor about y-axis through centre of gravity of motor located at x_2, y_2, z_2	kg·m^2
$I_{yy,3}$	Moment of inertia of base about y-axis through centre of gravity of base located at x_3, y_3, z_3	kg·m^2
k_H	Horizontal stiffness of resilient mount	N/m
k_V	Vertical stiffness of resilient mount	N/m
L_a	Vibratory acceleration level	dB
L_v	Vibratory velocity level	dB
m	Total mass of assembly	kg

Symbol	Term	Unit
m_1	Mass of fan	kg
m_2	Mass of motor	kg
m_3	Mass of base	kg
r	Radius of gyration	m
t	Time	s
T	Period of vibration	s
V	Instantaneous vibration velocity	mm/s or m/s
v_o	Reference vibration velocity	mm/s or m/s
V	Vibration velocity amplitude of peak	mm/s or m/s
V_{dB}	r.m.s. vibration velocity above a reference level of 10^{-9} m/s	dB
	$V_{dB} = 20\log_{10}\left(\frac{V_{r.m.s.}}{10^{-9}}\right)$	
$V_{r.m.s.}$	Overall root-mean-square velocity	mm/s or m/s
x, y, z	Cartesian coordinates	m
$\bar{z}$	Effective vertical offset of resilient mounts	m
X_G, Y_G, Z_G	Positions of centre of gravity of fans assembly relative to arbitrary origin	m
$\delta_{1,2,n}$	Individual deflections of resilient mounts	m
Σ	Summation	—
ω	Angular frequency = $2\pi f$	rad·s^{-1}

5 Mounting of test rig

5.1 General

Fans shall be mounted by one of the methods described in 5.2, 5.3 or 5.4, as appropriate.

Resilient mountings shall be chosen to give a uniform static deflection within $^{+20}_{-35}$ % of their nominal deflection. Fans which are resiliently mounted in normal applications shall be tested using the same type and number of mounts as used in that application. The support arrangement used, or existing at the time of the test, shall be described in the test report [see Clause 11 e)].

NOTE 1 The fan support arrangement may significantly affect the vibration levels measured on the fan structure. Mounting arrangements may be generally classified as stiff or resilient. In order to minimize the influence of the support condition on measured vibration levels, so that results from different tests may be readily compared, a resilient or soft-mounting arrangement for the fan is preferred. There is a risk of high-amplitude vibration when mounting stiffness results in the natural frequency f_n being near the frequency equivalent to the operating speed. For the purposes of this International Standard, a stiff mounting is considered to have a natural frequency f_n greater than 1,5 times the operating frequency. A resilient mounting is considered to have a natural frequency f_n less than 0,25 times the operating frequency.

NOTE 2 Tests using the rubber-rope method of suspension are recommended for design and development evaluation and/or as a grading exercise.

The test-rig arrangement will generally be determined by the nature and location of the test. For design/development evolution, sophisticated purpose-designed rigs are likely to be available. However, any arrangement of the test rig which does not readily permit the aerodynamic duty of the fan to be controlled, or in which the duty is otherwise unknown, may be unsuitable for tests in accordance with this specification where the vibration produced by the fan varies with duty. Wherever practicable, a standardized airway, as defined in ISO 5801, should be used.

NOTE 3 Two typical arrangements of fan-vibration test rigs are shown in Figures 1 and 2.

5.2 Resilient base mounting of fan

The natural frequencies of the fan on its mountings in the six possible degrees of freedom (see Figure 3) shall not be greater than 0,25 times of the slowest operational rotation frequency of the fan under test.

NOTE 1 A guide to calculating the natural frequencies is given in Annex A.

The mass of any additional attachments shall not exceed one-tenth of the normal mass of the unit under test, to reduce the influence of the mass and the moments of inertia of these parts on the vibration level.

NOTE 2 Where a fan is not normally equipped with resilient mountings, it may be necessary to fit special mounting brackets and isolators or other attachments to the fan in order to accommodate them.

No major flexural resonances of the support structure shall coincide with either the rotational frequencies of the fan under test or the rigid-body natural frequencies of the support arrangement, except when the fan and support are being investigated together.

NOTE 3 Fan reaction torque of the fan may be significant on a resiliently mounted arrangement (see A.3.2 for advice on inertia bases).

5.3 Mounting of fans with resilient elastic rope

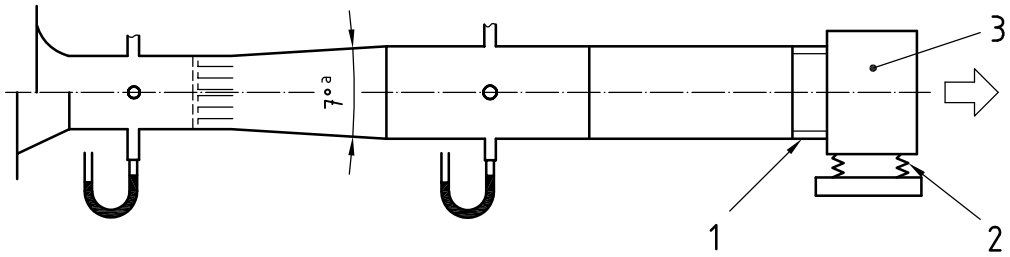
When testing fans with an integral motor which are to be supplied as single units without a mounting frame, these fans shall be mounted in an elastic-rope test rig (examples are shown in Figure 4).

NOTE 1 Low-frequency mounting permits consistent readings to be taken for comparison purposes under free-air conditions only.

When a duct connection is required to obtain the vibration characteristics at the duty point, a suitable flexible connection shall be used with horizontal elastic restraint if necessary.

The fan shall be supported by nylon slings attached to an assembly of braided rubber cords of a suitable number, length and diameter, arranged symmetrically with respect to the centre of gravity, to provide and overall deflection in the range 200 mm to 400 mm under the fan mass.

NOTE 2 This soft mounting may be conveniently suspended from an “A” frame structure.



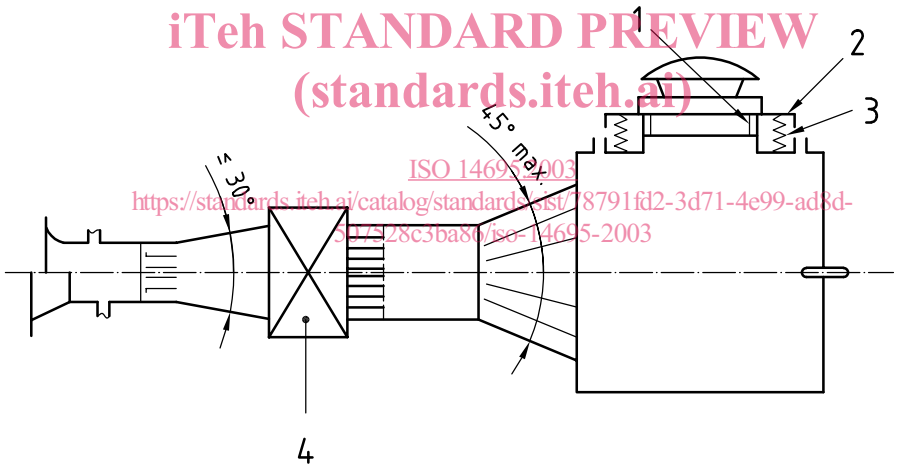
Key

1 flexible connection (diagrammatic)
2 resilient mounts
3 fan

NOTE This figure shows an arrangement suitable for a centrifugal axial fan or an in-line fan loaded by resistance screens on the inlet side. In some cases, it may be preferable to use a damper on the air-outlet side. This figure is generally in accordance with Figure 74 a) of ISO 5801:1997 with the addition of a flexible connection and resilient mounts between the fan and ducting.

[a] Angle at the top.

Figure 1 — Example of resilient mounting arrangement of a fan-vibration test rig

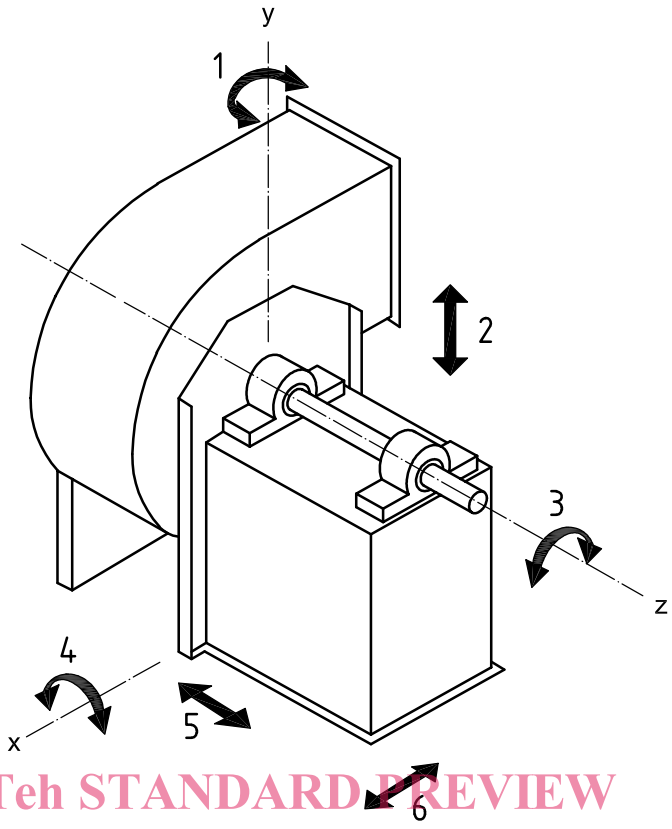


Key

1 flexible connection (diagrammatic) for tests
2 resilient mounted curb
3 resilient mounts
4 booster fan

NOTE This figure shows a roof extraction fan arranged for vibration testing purposes. The fan has been mounted on a curb which is resiliently mounted. The mass of the curb and natural frequency of the mounted test fan should be in accordance with 5.2. This figure is generally in accordance with that given in Figure B.2 of ISO 5801:1997, but with the addition of a flexible connection and resilient mounts between the fan and the outlet cowl.

Figure 2 — Example of arrangement for testing roof extraction fan



Key

1 yawing couple (rotation around y axis)
2 vertical inertia force (y axis)
3 rocking couple (rotation around z axis)
4 pitching couple (rotation around x axis)
5 longitudinal (axial) inertia force (z axis)
6 horizontal (transverse) inertia force (x axis)

Figure 3 — Degrees of freedom