
British Standard

Fans for general purposes

Part 6. Method of measurement of fan vibration

Foreword

This Part of BS 848 has been prepared under the direction of the Machinery and Components Standards Policy Committee.

BS 848 consists of a number of Parts as follows covering important aspects of fans which affect their design, manufacture and use.

Part 1 Methods of testing performance

Part 2 Methods of noise testing

*Part 3 Methods of site testing

*Part 4 Specification for fan dimensions

Part 5 Guide for mechanical and electrical safety

*Part 7 Specification for vibration and balancing

*Part 8 Fan terminology and classification

Vibration is recognized to be 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 forwarn 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 (appendix 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.

NOTE. The information which can be obtained from tests conducted in accordance with this standard (see clause 10) is neither necessary nor appropriate for quality grading purposes. Reference should be made to BS 848 : Part 7* for this purpose.

Whilst an open inlet/open outlet test may be useful as a quality guide, this 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 characteristic.

Although alternative standards exist which deal with vibration of machines generally (e.g. BS 4675 : Part 1), they presently have limitations because of their universal nature when considering a specific family of machines such as fans.

This Part of BS 848 describes the methods of measurement which will give consistent results and which may be used as a basis for the comparison between products. The amount of information which needs to be presented and the preferred units are given in BS 848 : Part 7*. 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.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

*In preparation.

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Section one. General

1 Scope

This Part of BS 848 describes a method of measuring the vibrational characteristics of fans of all types, except those designed solely for air circulation, e.g. ceiling fans and table fans. It describes a general method only and does not give criteria for interpretation of data (see BS 848 : Part 7*).

This standard describes the measurement of vibration that may be recorded as overall 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 standard.

NOTE. The titles of publications referred to in this Part of BS 848 are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 848 the definitions given in BS 3015 apply, together with the following.

2.1 displacement. A vector quantity that specifies the change of position of a body or particle with respect to a reference frame.

2.2 velocity. A vector quantity that specifies the time rate derivative of displacement.

2.3 acceleration. A vector quantity that specifies the time derivative of velocity.

2.4 antinode. A point, line or surface in a standing wave where some characteristic of the wave field has a maximum value.

2.5 frequency. The reciprocal of the period when the independent variable is time.

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

2.6 filter. A device for separating waves on the basis of their frequency.

2.7 band-pass filter. A wave filter with single transmission band extending from a lower cut-off frequency greater than zero to a finite upper cut-off frequency.

2.8 background vibration. All sources of vibration independent of the source.

2.9 simple harmonic motion (sinusoidal motion).

A motion that is a sinusoidal function of time.

2.10 mode of vibration. A characteristic pattern, in a structure undergoing vibration, assumed by the structure in which the motion of every particle is a simple harmonic with the same frequency.

2.11 coupled modes. Modes of vibration that are not independent but influence one another because of a transfer of energy from one mode to another.

2.12 damping. Dissipation of energy with time.

2.13 duty point (aerodynamic duty). The point on the fan performance curve at which the fan operates.

2.14 fan performance curve (fan characteristic). A plot of pressure rise developed by the fan against the flowrate through the fan.

2.15 harmonic of a periodic quantity. A sinusoidal quantity whose frequency is an integral multiple of the fundamental frequency of the quantity.

2.16 high-pass filter. A wave filter having a single transmission band extending from some cut-off frequency greater than zero up to infinite frequency.

2.17 low-pass filter. A wave filter having a single transmission band extending from zero frequency up to some cut-off frequency which is not infinite.

2.18 natural frequency. The frequency of free vibration of a structure.

2.19 peak-to-peak value. The algebraic difference between the two extreme values of the quantity.

2.20 radius of gyration (moment of inertia). A measure of the distribution of mass about a chosen axis and given as the square root of the moment of inertia about that axis divided by the mass.

2.21 resilient mount. A mount with elastic characteristics, i.e. no significant permanent deformation in the mount under normal load conditions.

2.22 stiffness. The ratio of change of force (or torque) to the corresponding change in translational (or rotational) deflection of an elastic element.

2.23 transducer. A device that receives energy from one system and supplies energy, of either the same or different kind, to another system in such a manner that the desired characteristics of the input energy appear at the output.

* In preparation.

3 Symbols and units

For the purposes of this Part of BS 848 the following symbols and units apply.

Symbol	Description	Unit
a	instantaneous vibration acceleration	m/s^2
a_o	reference vibration acceleration	m/s^2
A	peak vibration acceleration amplitude	m/s^2
A_{dB}	r.m.s. vibration acceleration level above a reference of 10^{-6} m/s^2	dB
	$A_{dB} = 20 \log_{10} \left(\frac{A_{r.m.s.}}{10^{-6}} \right)$	
$A_{r.m.s.}$	r.m.s. vibration acceleration amplitude	m/s^2
d	instantaneous vibration displacement	μm , mm or m
D	peak vibration displacement amplitude	μm , mm or m
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 system centre of gravity	$\text{kg}\cdot\text{m}^2$
I_T	moment of inertia of system about z -axis through system centre of gravity located at X_G, Y_G, Z_G	$\text{kg}\cdot\text{m}^2$
$I_{zz,1}$	moment of inertia of fan about z -axis through fan centre of gravity located at x_1, y_1, z_1	$\text{kg}\cdot\text{m}^2$
$I_{zz,2}$	moment of inertia of motor about z -axis through motor centre of gravity located at x_2, y_2, z_2	$\text{kg}\cdot\text{m}^2$
$I_{zz,3}$	moment of inertia of base about z -axis through base centre of gravity located at x_3, y_3, z_3	$\text{kg}\cdot\text{m}^2$
$I_{xx,1}$	moment of inertia of fan about x -axis through fan centre of gravity located at x_1, y_1, z_1	$\text{kg}\cdot\text{m}^2$
$I_{xx,2}$	moment of inertia of motor about x -axis through motor centre of gravity located at x_2, y_2, z_2	$\text{kg}\cdot\text{m}^2$
$I_{xx,3}$	moment of inertia of base about x -axis through base centre of gravity located at x_3, y_3, z_3	$\text{kg}\cdot\text{m}^2$
$I_{yy,1}$	moment of inertia of fan about y -axis through fan centre of gravity located at x_1, y_1, z_1	$\text{kg}\cdot\text{m}^2$
$I_{yy,2}$	moment of inertia of motor about y -axis through motor centre of gravity located at x_2, y_2, z_2	$\text{kg}\cdot\text{m}^2$
$I_{yy,3}$	moment of inertia of base about y -axis through base centre of gravity located at x_3, y_3, z_3	$\text{kg}\cdot\text{m}^2$
k_H	horizontal stiffness of resilient mount	N/m
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	is the total mass of assembly	kg
m_1	mass of fan	kg
m_2	mass of motor	kg
m_3	mass of base	kg
r	radius of gyration	m

Symbol	Description	Unit
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	peak vibration velocity amplitude	mm/s or m/s
V_{dB}	r.m.s. vibration velocity above a reference level of 10^{-9} m/s $V_{dB} = 20 \log_{10} \left(\frac{V_{r.m.s.}}{10^{-9}} \right)$	dB
$V_{r.m.s.}$	overall root mean square velocity	mm/s or m/s
$\left. \begin{matrix} x \\ y \\ z \end{matrix} \right\}$	cartesian coordinates	m
$\bar{z}$	effective vertical offset of resilient mounts	m
$\left. \begin{matrix} X_G \\ Y_G \\ Z_G \end{matrix} \right\}$	positions of fan assembly centre of gravity relative to arbitrary origin	m
$\delta_{1,2,...,n}$	individual deflections of resilient mounts	m
Σ	summation	—
ω	angular frequency = $2\pi f$	Hz

Section two. Method of measurement

4 Mounting of test rig

4.1 General

Fans shall be mounted by one of the methods described in 4.2, 4.3 or 4.4, as appropriate.

Resilient mountings shall be chosen to give a uniform static deflection within $\pm 20\%$ of the 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 10 (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.

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

NOTE 3. The test rig arrangement will generally be determined by the nature and location of the test. For design/development evaluation, sophisticated purpose-designed rigs are likely to be available. However, any arrangement of 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 BS 848 : Part 1, should be used.

NOTE 4. Two typical arrangements of fan vibration test rigs are shown in figures 1 and 2.

4.2 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 be not greater than one-quarter of the slowest operational rotational frequency of the fan under test.

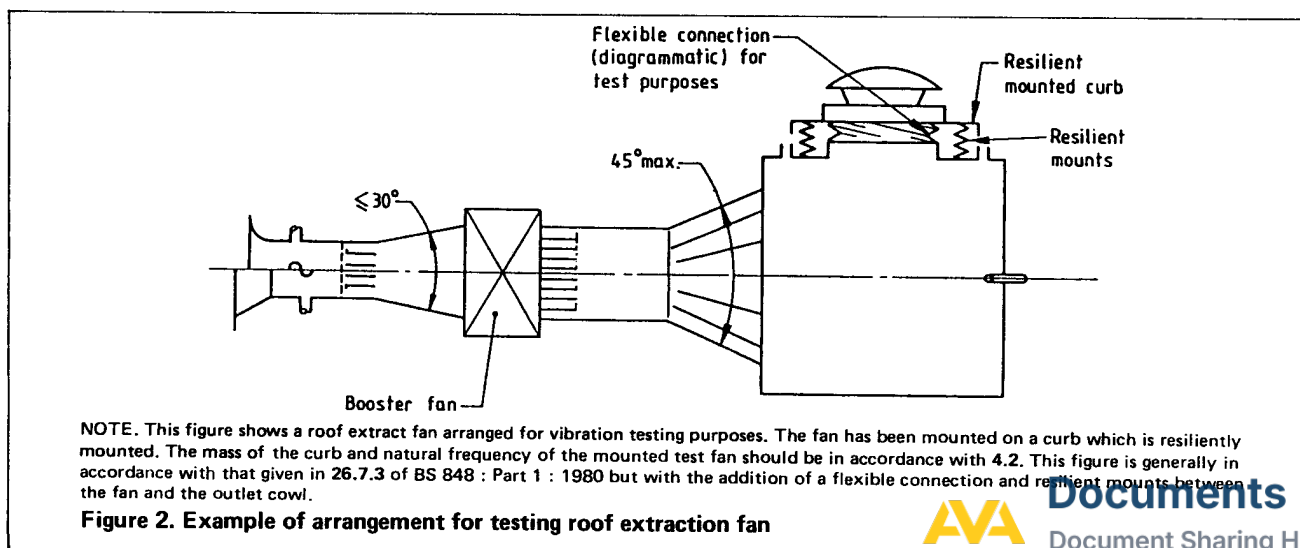
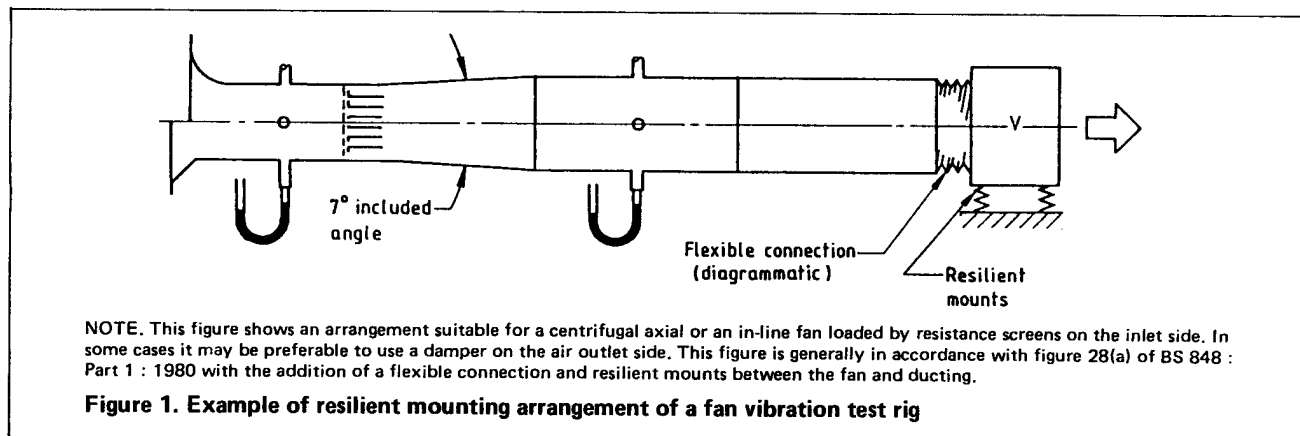
NOTE 1. A guide to calculating the natural frequencies is given in appendix A.

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 may be significant on a resiliently mounted arrangement (see A.3.2 for advice on inertia bases).



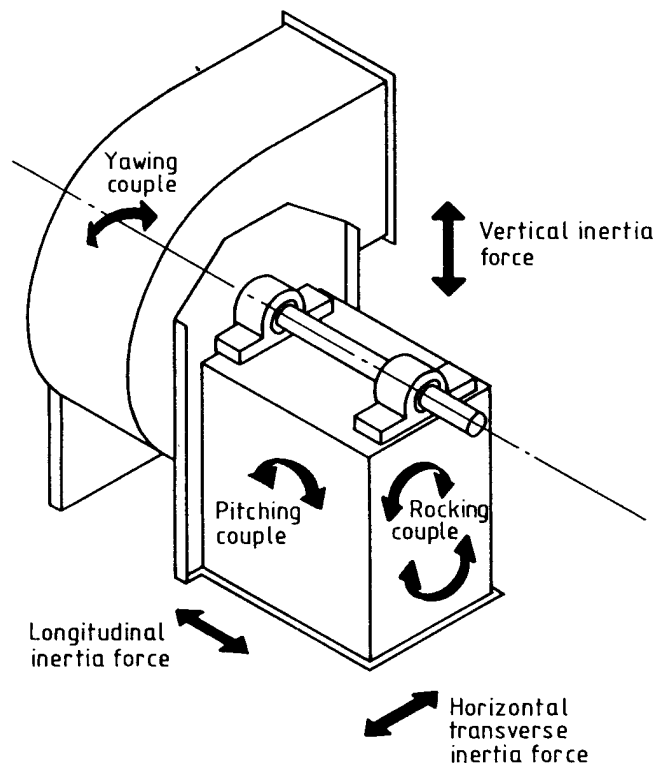


Figure 3. Degrees of freedom

4.3 Resilient elastic rope mounting of fans

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, then 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 an overall deflection in the range 200 mm to 400 mm under the fan mass. The braided rubber cord shall be in accordance with British Standard 2F 70 for heavy duty cord 5 mm to 26 mm in

diameter and British Standard 2F 71 for light duty cord 3 mm to 11 mm in diameter.

NOTE 2. This soft mounting can be conveniently suspended from an 'A' frame structure.

4.4 Stiff mounting of fans

Prior to undertaking vibration measurements, the mounting of the fan shall be inspected to ensure that the fixing of foundation bolts are sound and the bolts properly tightened.

NOTE. Fans that either cannot readily be resiliently mounted or that are installed at site on a relatively stiff foundation, e.g. terminal flange mounted or foot mounted, require special consideration. It may be difficult to comply with 4.5 in such circumstances. A valid comparison of the vibration magnitude for such fans with others of the same type can only be made if the foundation arrangements have similar dynamic characteristics. This implies that the dynamic stiffness, damping and effective mass of the structural mounting and, where applicable, the supporting soil, should be similar for the cases being compared.