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INTERNATIONAL STANDARD

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Rotating electrical machines –
Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity

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Machines électriques tournantes –
Partie 14: Vibrations mécaniques de certaines machines de hauteur d'axe supérieure ou égale à 56 mm – Mesurage, évaluation et limites de l'intensité vibratoire

IEC 60034-14:2018-08(en-fr)

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ROTATING ELECTRICAL MACHINES –

Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity

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International Standard IEC 60034-14 has been prepared by IEC technical committee 2: Rotating machinery.

This fourth edition cancels and replaces the third edition, published in 2003, and its amendment 1, published in 2007. It constitutes a technical revision.

The significant technical changes with respect to the previous edition are:

a) 6.2 is significantly changed to better explain the definition "free suspension".

b) 6.3: a second method of rigid mount is added since the first method is not always possible on the test floor.

c) 7.1: an improved option for shaft key is defined.

d) Clause 8: considerable effort to harmonize with NEMA MG 1 and IEEE 841 and API 541, and also establish levels which are achievable and more in line with best practices. Table 1 is reduced to two shaft-height range sections.

e) 8.2: definition of twice line frequency simplified along with Figure 7 added.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
2/1906/FDIS	2/1914/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60034 series, published under the general title *Rotating electrical machines*, can be found on the IEC website.

NOTE For A table of cross-references of all IEC TC 2 publications can be found in the IEC TC 2 dashboard on the IEC website.

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ROTATING ELECTRICAL MACHINES –

Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity

1 Scope

This part of IEC 60034 specifies the factory acceptance vibration test procedures and vibration limits for certain electrical machines under specified conditions, when uncoupled from any load or prime mover.

It is applicable to DC and three-phase AC machines, with shaft heights 56 mm and higher and a rated output up to 50 MW, at operational speeds from 120 min^{-1} up to and including 15 000 min^{-1}.

This document is not applicable to machines mounted *in situ* (on site), three-phase commutator motors, single-phase machines, three-phase machines operated on single-phase systems, vertical waterpower generators, turbine generators greater than 20 MW and machines with magnetic bearings or series-wound machines.

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NOTE For machines measured *in situ*, refer to applicable parts of ISO 20816, ISO 10816 and ISO 7919.

2 Normative references

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The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.

IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60034-7, *Rotating electrical machines – Part 7: Classification of types of constructions and mounting arrangements (IM Code)*

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

ISO 10817-1, *Rotating shaft vibration measuring systems – Part 1: Relative and absolute sensing of radial vibration from rotating shafts*

ISO 20816-1, *Mechanical vibration – Measurement and evaluation of machine vibration – Part 1: General guidelines*

ISO 21940-32, *Mechanical vibration – Rotor balancing – Part 32: Shaft and fitment key convention*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60034-1 apply.

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- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 Measurement quantities

4.1 General

Measurement quantities are the vibration displacement and vibration velocity at the machine bearings and the relative shaft vibration displacement within or near to the machine bearings.

4.2 Vibration magnitude

The criterion for the vibration magnitude at the machine bearings shall be the broadband r.m.s. value of the vibration displacement in micrometres or the vibration velocity in millimeters per second in the frequency range specified in Clause 5. The maximum value, determined at the prescribed measurement positions and prescribed measuring variable, according to this standard, characterizes the vibration magnitude of the machine.

Induction motors (especially of two pole type) frequently show vibration beating at twice slip frequency. In these cases, the decisive vibration magnitude shall be determined from the relationship:

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$$x_{\text{r.m.s.}} = \sqrt{\frac{x_{\max}^2 + x_{\min}^2}{2}}$$

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where

x_{max} is the maximum r.m.s. value of vibration displacement or vibration velocity;

x_{min} is the minimum r.m.s. value of vibration displacement or vibration velocity.

The sample rate shall be chosen large enough to reliably capture the maximum and minimum values of the vibration.

NOTE Large AC induction machines running at very low slip values at no load may require several minutes to more than ten minutes for such measurements to be completed at each vibration measuring position.

4.3 Relative shaft vibration

The criterion adopted for the relative shaft vibration shall be the vibratory displacement $S_{\text{p-p}}$ in the direction of measurement from ISO 20816-1.

5 Measurement equipment

The measurement equipment shall be capable of measuring broadband r.m.s. vibration with flat response over a frequency range of 10 Hz to 1 000 Hz, in accordance with the requirements of ISO 2954. However, for machines with speeds approaching or below 600 min^{-1}, the lower limit of the flat response frequency range shall not be greater than 2 Hz.

Measurement equipment for relative shaft vibration measurements shall comply with the requirements in ISO 10817-1.

Multi-directional vibration sensors shall not be used.

NOTE Multi-directional sensors do not provide proper vibration measurement in all directions when mounted in only one location.

6 Machine mounting

6.1 General

The vibration of an electrical machine is closely linked with the mounting of the machine. To permit evaluation as far as balance and vibration of rotating electrical machines are concerned, it is necessary to measure the vibration on the machine alone, under properly determined test conditions, to enable reproducible tests to be carried out and to provide comparable measurements.

6.2 Free suspension

This condition is achieved by suspending the machine on a spring or by mounting on an elastic support (springs, rubber, etc.).

The highest natural oscillation frequency (f_{no}) of the suspension system and machine, shall be less than 1/3 of the frequency f_1 corresponding to the speed of the machine under test, as defined in 7.3. Based on the mass of the machine being tested, the necessary elasticity of the suspension system as a function of rated speed from 600 min^{-1} to 3 600 min^{-1} can be determined from Figure 1. For speeds lower than 600 min^{-1} measurements in free suspension are not practical. For speeds greater than 3 600 min^{-1}, the static displacement Z should be not less than the value for 3 600 min^{-1}.

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The curve in Figure 1 presents the minimum elastic displacement to attain the necessary vertical rigid body natural oscillation, which is usually the highest rigid body natural frequency. Static displacement Z is expressed as:

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$$Z = \frac{a^2 g}{(2\pi n)^2} \quad , a = \frac{f_1}{f_{no}}; \ a \geq 3$$

where

Z is the displacement in m,

n is the rated speed in units of s^{-1}, and

g is the acceleration of gravity (9,81 m/s^2).

When a is set to 3, then the curve in Figure 1 is generated.

6.3 Rigid mounting

6.3.1 Foundation

6.3.1.1 General

During the shop running test of the assembled machine, vibration measurements shall be made with the machine properly shimmed and securely fastened to a massive foundation or test floor stand. Elastic mounts are not permitted.

The horizontal and vertical natural frequencies of the complete test arrangement shall not coincide within:

a) ± 10 % of the rotational frequency of the machine;

b) ± 5 % of twice the rotational frequency, or

c) ± 5 % of once and twice the electrical line frequency.

Either one of the following two mounting conditions may be chosen by the manufacturer.

6.3.1.2 Rigid mounting on massive foundation

One indication of massive foundation is when the vibration velocity measured in the horizontal and vertical directions at the machine feet (or at the base frame near to the bearing pedestals or stator feet) does not exceed 30 % of the maximum velocity, which is measured at the adjacent bearing housing in the same measurement direction. The ratio of foot to bearing vibration velocities is valid for the rotational frequency component or twice-line frequency component (if the latter is being evaluated).

NOTE 1 The rigidity of a foundation is a relative quantity. It is compared 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.

NOTE 2 If the machine is to be supported in the field by a structure other than a massive foundation, it may be necessary to perform a system dynamic analysis to make the necessary changes to the foundation dynamic stiffness.

6.3.1.3 Rigid mounting on test floor stand

This condition is achieved by mounting the machine on an adequately rigid test foundation free of resonances at forcing frequencies, see 6.3.1.1.

NOTE This mounting is the most used in manufacturers test labs.

6.3.2 Horizontal machines

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The machine under test shall be bolted or clamped using all bolt-hole positions to a foundation that meets the requirements of 6.3.1.2 or 6.3.1.3.

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There are constructions and mountings in which the above fixing conditions cannot be met, such as single-bearing machines. In those cases there should be an agreement between the supplier and customer.

6.3.3 Vertical machines

Vertical machines shall be mounted onto a solid rectangular or circular steel plate with a bore hole in the centre of the shaft extension, a machined surface for the flange of electrical machine being measured and holes provided for fasteners or clamps. The steel plate thickness shall be at least three times greater than the machine flange thickness, five times is recommended. The edge length respective to the diameter shall be at least equal to the height of the top bearing, L. Figure 6 is an example for IM V1 (see IEC 60034-7).

The steel base shall be clamped firmly and tilt safe to a solid floor and meet the requirements to 6.3.1.2 or 6.3.1.3. The flange connection shall use the correct number of fasteners or clamps. If the above method of mounting is not reasonable, other arrangements can be per agreement between supplier and customer.

6.4 Active environment determination

The support systems described in 6.2 and 6.3 are considered passive, admitting insignificant external disturbances to the machine. When, for the same measurement position, the vibration magnitude with the machine at standstill exceeds 25 % of the value when the machine is running, then an active environment is said to exist and this standard does not apply (see ISO 20816-1).

7 Conditions of measurement

7.1 Key

For the balancing and measurement of vibration on machines provided with a shaft extension keyway, the keyway shall be considered according to ISO 21940-32.

7.2 Measurement positions and directions

7.2.1 Measurement positions for vibration

The location of the preferred measurement positions and directions to which the levels of vibration magnitude apply are shown in Figure 2 for machines with end-shield bearings and in Figure 4 for machines with pedestal bearings. Figure 3 applies to those machines where measurement positions according to Figure 2 are not possible without disassembly of parts. When measurements cannot be performed per Figure 2 or Figure 3, there should be an agreement between supplier and customer.

Figure 6 applies to machines mounted in the vertical position.

NOTE 1 Measurement according to Figure 3 might be on the frame as close to the bearing housing as possible.

NOTE 2 Axial vibration measurement may not be possible without disassembly on both ends. If a machine has thrust bearings, this may be per agreement between supplier and customer, see 8.3.

7.2.2 Measurement positions for relative shaft displacement

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Non-contacting transducers shall be installed inside the bearing, measuring directly the relative shaft journal displacement, or (when inside mounting is not possible) adjacent to the bearing shell. The preferred radial positions are as indicated in Figure 5.

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7.3 Test conditions

Machines shall be tested at no-load with all relevant quantities at their rated value.

Fixed speed AC machines shall be run with a sinusoidal supply voltage according to IEC 60034-1.

The test shall be performed at each rated fixed speed or over the rated speed range for variable frequency drives. For all tested speeds, the values shall not exceed the corresponding limit in Table 1.

In order to discern the mechanically induced vibration from other vibration excitation forces, it is recommended that DC machines are tested with a low current ripple supply or pure DC.

NOTE Tests with variable-frequency power supply normally only confirm mechanically induced vibrations. It is possible that electrically induced vibrations will be different. If possible, the tests with the actual converter to be installed with the motor on site will provide better information about vibration behaviour.

For routine testing of variable-speed machines, it is permitted to test at a single speed based upon information obtained during type test.

For machines that are bi-directional, the vibration limits apply for both directions of rotation, but need to be measured in only one direction.

7.4 Vibration transducer

The mounting of the transducer used for vibration measurement on the machine surface shall be as specified by the manufacturer of the transducer and shall not disturb the vibratory condition of the machine under test.

For this, it is necessary that the total coupled mass of the transducer assembly is less than 1/50 of the mass of the machine.

8 Limits of bearing housing vibration

8.1 Limits of vibration magnitude

The limits apply to the measured broadband r.m.s. vibration velocity and displacement in the frequency range specified in Clause 5.

The vibration magnitude for DC and three phase AC machines with shaft heights 56 mm and higher, for one of either of the two mounting conditions according to Clause 6, shall not exceed the limits specified in Table 1. Limits are given for two vibration grades. When no grade is specified, machines complying with this standard shall be grade A.

For routine tests of standard machines with rotational speeds less than 600 min^{-1}, vibration is to be expressed in units of displacement. For rotational speeds from 600 min^{-1} up to 15 000 min^{-1}, vibration is to be expressed in units of velocity.

When the routine test is made with a free-suspension mounting condition, the type test should also include testing with rigid mounting. This is valid for the whole speed range of this standard.

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Table 1 – Limits of maximum vibration magnitude in displacement (r.m.s.) and velocity (r.m.s.) for shaft height *H*

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Vibration grade	Shaft height, mm	56 ≤ H ≤ 132		H > 132	
	Mounting	Displacement µm	Velocity mm/s	Displacement µm	Velocity mm/s
A	Free suspension	45	2,8	45	2,8
	Rigid mounting	–	–	37	2,3 2,8*
B	Free suspension	18	1,1	29	1,8
	Rigid mounting	–	–	24	1,5 1,8*

Grade A applies to machines with no special vibration requirements.

Grade B applies to machines with special vibration requirements.

Rigid mounting is not considered acceptable for machines with shaft heights less than or equal to 132 mm.

Vibration at frequencies above 1 000 Hz should be filtered out.

The shaft height of a machine without feet, or a machine with raised feet, or any vertical machine is to be taken as the shaft height of a machine in the same basic frame, but of the horizontal shaft foot-mounting type.

* This level is the limit when the twice line frequency vibration level is dominant as defined in 8.2 and explained in Figure 7.

NOTE 1 The manufacturer and the purchaser take into account that the instrumentation can have a measurement tolerance of ± 10 %.

NOTE 2 A machine which is well-balanced in itself and of a grade conforming with Table 1 may exhibit large vibrations when installed on site arising from various causes, such as unsuitable foundations, reaction of the driven machine, current ripple from the power supply, etc. Vibration may also be caused by driving elements with a natural oscillation frequency very close to the excitation due to the small residual unbalance of the rotating masses