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Electrodynamic vibration generating systems — Performance characteristics

Systèmes électrodynamiques utilisés pour la génération de vibrations — Caractéristiques de performance

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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 5344 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 6, *Vibration and shock generating systems*.

This second edition cancels and replaces the first edition (ISO 5344:1980), which has been technically revised.

Considered responses to all of the proposed substantive changes to ISO 5344:1980 are incorporated in this second edition. Changes favouring the specific design of individual sources were rejected. Regarding endurance testing, a compromise is incorporated, providing a less expensive, but hopefully adequate, assurance of reliability.

Introduction

Users want their equipment to operate for long period without malfunction. A major purpose of this International Standard is to establish procedures to measure performance and to provide ways to ensure the reliability of electrodynamic vibration generation equipment and systems. Some assurance of reliability, but not conclusive, is provided by endurance tests on the vibrator, amplifier and the system as a whole.

If all sources of electrodynamic vibration generation equipment and systems use the same procedures, these procedures define the meanings of the performance statements and reliability statements. Comparisons of the performance and reliability statements of the different sources become useful.

Many of these procedures are suitable for incorporation in a purchase specification to state the acceptance testing to be carried out upon delivery.

Others, particularly those related to endurance testing, are lengthy and expensive, and typically are performed by the source at the end of the product development process, before the start of series production. These procedures typically are used to establish and confirm the rated performance stated in the sales literature. After discussions with the proposed sources, the writer of the purchase specification may propose abbreviated procedures for equipment acceptance testing, or alternatively, may propose to accept written assurances that the full procedures have been performed by the source with mutually satisfactory results.

INTERNATIONAL STANDARD **ISO 5344:2004(E)**

Electrodynamic vibration generating systems — Performance characteristics

1 Scope

This International Standard specifies the performance characteristics and performance test conditions for electrodynamic vibration generator systems and provides a list of additional equipment characteristics (see Annex A) that can be declared by the equipment manufacturer. This information can be used by the user or the writer of specifications for equipment for the selection of such a system, taking into account its application.

This International Standard establishes procedures for calculating the system performance of a system comprising an amplifier from one source and a vibrator from a different source. Such a calculated system performance is less precise than performance measured on a system comprising the actual vibrator and amplifier, and a reserve of calculated force is recommended. It can be desirable to specify separately the acquisition of needed vibrator and/or amplifier interface data, particularly if a vibrator or amplifier is to be acquired to add to an existing installation. It can also be desirable to specify the responsibility for the calculation of performance.

This International Standard is applicable to equipment producing sine, random and impulse rectilinear vibration. It is implied that all systems are usable for sine testing at least at a low level, since sine capability is needed for specimen response evaluation and transfer function measurements for random and impulse testing. When random capability is specified, it is implied that some sine capability is also available. Similarly, when impulse capability is specified, it is implied that some sine, but not necessarily random, capability is available.

NOTE Three groups of people are expected to use this International Standard: the supplier of the equipment, the purchaser of the equipment, and the organization that tests the equipment. The supplier of the equipment states that “rated” performance is available, typically as stated in sales literature. The purchaser states the “specified” performance of the equipment that he will accept, typically less than or equal to the rated performance. The test organization “provides” the results of its tests and observations, typically by a written report, which may include the conditions and accuracy of each measurement, and illustrations such as waveforms, performance graphs and tables of values.

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 2041:1990, *Vibration and shock — Vocabulary*

ISO 15261, *Vibration and shock generating systems — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 15261 and the following apply.

3.1

electrodynamic vibration generator

vibrator

vibration generator which derives its vibratory force from the interaction of a magnetic field of constant value, and a coil of wire contained in it which is excited by a suitable alternating current

[ISO 2041:1990]

NOTE 1 Unless specifically restricted to the moving element, body and base of the vibrator machine, this includes the flexible field, control and drive cables, coolant hoses, field supply, and cooling, demagnetizing, protective and safety systems.

NOTE 2 In this International Standard, the subscript “ v ” is used to indicate vibrator, short for electrodynamic vibration generator. The word vibrator, which has the same meaning, is the term commonly used in industry.

3.2

power amplifier

amplifier

power electronic device capable of providing the voltage and current used to drive the vibrator

NOTE Unless otherwise specified, this includes the cooling, protective and safety systems.

3.3

system

combination of a power amplifier and an electrodynamic vibration generator to provide vibratory force

NOTE The following are excluded from this International Standard, but are included in the more inclusive electrodynamic vibration test facility system:

- the input signal source and control (typically providing controlled sinusoidal, random or shock simulation signals);
- specimen mounting fixtures and auxiliary tables;
- measuring instrumentation (e.g. accelerometers and conditioning and analysis electronics);
- mains electrical power cables and coolant hoses, or piping to and between the power amplifier, vibrator field supply, and vibrator and amplifier cooling supplies;
- air conditioning to remove generated heat not removed by the cooling systems;
- a vibration-isolated inertia block to inhibit the transmission of vibratory forces from the vibrator to the surroundings.

3.4

equipment source

source

supplier of the equipment being acquired or to be used in the system

NOTE 1 When a system is purchased from a single source, that source usually is the manufacturer or his agent. When the components of a system are being purchased from more than one source, the sources are usually the manufacturers of the individual components or their agents. When an organization wishes to acquire a new component (e.g. a switching amplifier) to be combined with an existing component (e.g. a vibrator in the test laboratory of the organization), the source of the vibrator is the vibration test laboratory.

NOTE 2 The vibration test laboratory, or other similar non-commercial source, may have difficulty acquiring the data needed to assure that the resulting system achieves the desired system specifications.

3.5

drive coil

component of the electrodynamic vibration generator, designed to provide, by means of interaction between the alternative current in the drive coil and the static magnetic field, the vibratory force proportional to the drive coil current

NOTE For most electrodynamic vibration generators, the drive coil is attached to the moving element. For transformer coupled vibrators, the drive coil is stationary and is coupled by transformer action to a shorted ring on the moving element.

3.6

linear power amplifier

power amplifier having an output proportional to the input

NOTE 1 Typically, the large linear power amplifiers designed to drive vibrators have low distortion (0,1 % to 0,3 %) when they are new or well maintained, but have high internal power dissipation, so necessitate a way of disposing of the excess heat, and are more expensive than switching power amplifiers.

NOTE 2 Small vibrators are sometimes driven by linear audio-power amplifiers or arrays of linear audio-power amplifiers. Moderately priced units typically have 0,1 % distortion, and higher performance and price units are available with 0,01 % distortion.

3.7

switching power amplifier

power amplifier having an output that switches alternately between a negative value and a positive value at a high frequency

NOTE 1 If the output is positive for a greater fraction of the high frequency cycle than it is negative, the mean output is positive. Filtering, including the effects of the drive coil inductance and the moving mass, serves to smooth the current through the drive coil. The technique results in low internal power dissipation. Switching power amplifiers typically are smaller and less expensive than linear power amplifiers of the same output capability, but may have higher distortion.

NOTE 2 The earlier switching power amplifiers used to drive vibrators had switching frequencies around 40 kHz and distortions of about 5 % to 15 %. Modern switching power amplifiers are available with switching frequencies of about 150 kHz and distortion of about 1,5 % to 5 %. As faster switching transistors become available, higher switching frequencies will be possible, and the distortion will be reduced further. When switching frequencies reach the megahertz region, substantial feedback around the output stage is possible, and the switching amplifier distortion will reach the 0,1 % to 0,3 % range of the linear power amplifiers.

3.8

force

vibratory force resulting from a varying current, in a steady magnetic field, which is applied to the structure of the moving element and the attached specimen

NOTE Due to losses, resonances and travel limitations, not all of this force is available to accelerate the moving element and attached specimen and/or to deflect the moving element suspension springs. The magnitude of the force is defined by the resulting acceleration:

$$F = \left(m_\mathrm{e} + m_\mathrm{t}\right) a$$

where m_e and m_t are the masses of the moving element and attached load, respectively, and a is the resulting acceleration. This definition applies to sine, random and impulse functions of a and F.

3.9

frequency range f_min to f_max

frequency range over which the full rated performance of a variable can be achieved

NOTE 1 Since the frequency range for one variable differs from the frequency range of another variable, the frequency range should be separately specified for each variable and for each load.

NOTE 2 With regard to the force-generating capability, the values of f_{min} and f_{max} should be individually specified for both vibrator and system rated sine, random and impulse forces for each of the masses m_{t}, and for the amplifier rated sine, random, and impulse output. If factors other than the force-generating capability limit the frequency range of operation, they should be specified.

EXAMPLE

a) At low frequencies, examples of areas that may cause problem are

- ratio of body mass to moving mass,
- the pedestal-body suspension stroke limitations,
- distortion,
- transverse motion,
- the moving element stroke limitations,
- moving element side load capability, and
- moving element suspension heating.

b) At high frequencies, examples of areas that may cause problems are

- moving element mechanical resonance,
- diaphragmatic effect of the moving element table (diaphragming),
- distortion,
- transverse motion, and
- moving element to load stiffness.

3.10
test mass

m_{t}

mechanical mass used for the testing of systems and electrodynamic vibration generators

NOTE Except for the special case of m_0, the subscript " t " indicates the magnitude of the mass by the magnitude of the sinusoidal acceleration achievable with the mass:

m_0 is the special case of zero load, where only the moving element is driven;

m_1 means that 10 m/s^2 ($\approx 1\, g_{\mathrm{n}}$) is achievable;

m_4 means that 40 m/s^2 ($\approx 4\, g_{\mathrm{n}}$) is achievable;

m_{10} means that 100 m/s^2 ($\approx 10\, g_{\mathrm{n}}$) is achievable;

m_{20} means that 200 m/s^2 ($\approx 20\, g_{\mathrm{n}}$) is achievable;

m_{40} means that 400 m/s^2 ($\approx 40\, g_{\mathrm{n}}$) is achievable.

Unless otherwise specified, only m_0, m_{10} and m_{40} are used.

3.11
amplifier test load

$Z_{\mathrm{a,t}}$

electric load of the amplifier, designed to be used when testing as a system is not possible (usually because the amplifier and vibrator sources differ)

NOTE Tests with the loads $Z_{\mathrm{a,t}}$ are used to acquire data for the prediction of system performance. The subscript t indicates the operation mode: s for sine, r for random, and i for impulse. See 7.2 for properties and the calculation of load magnitudes.

3.12
amplifier apparent power

product of the amplifier output current and the amplifier output voltage under specified conditions

NOTE See Note to 7.1.2 for improved size designation.

3.13
standard random spectral shape

random motion spectrum of the following shape, unless otherwise specified:

$$\Phi(f) = 0 \qquad \text{for } f < 20\ \text{Hz};$$

$$\Phi(f) = \left(\frac{f}{100}\right)^2 \Phi_0 \qquad \text{for } 20\ \text{Hz} \leqslant f < 100\ \text{Hz} \qquad \text{(20 dB per decade)}$$

$$\Phi(f) = \Phi_0 \qquad \text{for } 100\ \text{Hz} \leqslant f < 2\,000\ \text{Hz} \qquad \text{(constant)}$$

$$\Phi(f) < \Phi_0 \left(\frac{2\,000}{f}\right)^4 \text{ or } 10^{-4}\Phi_0 \qquad \text{for } f \geqslant 2\,000\ \text{Hz} \qquad \text{(allowable spill-over)}$$

NOTE $\Phi(f)$ is the magnitude of the acceleration spectral density function, defined as the limit as Δf approaches 0 of $a_{\mathrm{n}}^2 / \Delta f$, where a_{n} is the root-mean-square value of a narrow-band random acceleration of bandwidth Δf centred about the frequency f.

3.14
impulse

short-duration waveform used to provide a shock excitation to the specimen

NOTE 1 There should be agreement on the acceleration time history of the impulse to be used before any of the impulse clauses of this International Standard may be used.

NOTE 2 An impulse is specified by an acceleration time history. For electrodynamic systems, the frequency components of the acceleration time history or of the wavelets used to produce an acceleration response spectrum are specified over the frequency range.

NOTE 3 Typically, the high frequency spill-over problems of impulse testing are more severe than for random vibration testing because the high amplifier output, and clipping, generate larger distortion components.

NOTE 4 Vibrators with transformer driver coils sometimes are used for high acceleration impulses. Typically, such vibrators have the advantage of very strong moving elements. As a disadvantage, they have displacement limits that are particularly serious for the smaller vibrators. Moving element cooling of the strongest types of these vibrators is difficult, which may be a problem if the same vibrator is to be used for sine and random testing as well as for impulse testing.

3.15
spill-over

undesired vibration (or signal) in the frequency range higher than the specified frequency range

EXAMPLE For vibration tests specified only to 2 000 Hz, spill-over is vibration excitation above 2 000 Hz.

NOTE Typically, spill-over is caused by loose elements of the moving element or test load, inadequate filtering, or by excessive current distortion.

3.16
distortion

undesired change in the waveform

[ISO 2041:1990]

NOTE 1 Distortion is distinguished from noise and hum, which are dealt with separately in this International Standard.

NOTE 2 For a good electrodynamic vibration generating system, the presence of distortion is a very sensitive indication that something is wrong. Excessive distortion is a signal calling for corrective action. The user is advised to find the problem, and correct it, before running an environmental test that would be invalid. The cause of the distortion may be anywhere, including a loose bolt mounting the specimen to the table, a failed amplifier output transistor, an obstruction in a cooling system, or an attempt to drive the amplifier or vibrator beyond its limits.

NOTE 3 For properly maintained electrodynamic vibration generation systems, a major cause of distortion is non-linearity or clipping in the power amplifier. Some of the low frequency distortion, below 50 Hz to 100 Hz, is typically caused by suspension stiffness non-linearity and/or the non-uniformity of the field in the magnetic gap. In this frequency range, these distortions can exceed those due to power amplifier non-linearity.

NOTE 4 The distortion process generates harmonics of the input signal which excite higher frequency resonances of the specimen. Both distortion products in the operating band, typically 20 Hz to f_{max}, and distortion products which cause excitation above f_{max} are troublesome (see 3.15).

NOTE 5 Distortion may be specified for any variable of the system: current, voltage, acceleration, velocity or displacement. Current distortion is the most useful distortion measure for vibration test systems. It is used to predict system distortion and spill-over.

NOTE 6 It is tempting to specify the measurement of acceleration distortion directly, but such a measurement is unique to the particular moving element/load combination being measured, and does not provide data that are useful for the prediction of distortion with other table loads.

3.17
standard acceleration due to gravity
g_{n}
value for the acceleration due to gravity as defined for shock and vibration use in ISO 2041

NOTE 1 According to ISO 2041, g_{n} equals 9,806 65 m/s^2.

NOTE 2 In vibration testing, acceleration magnitude is often expressed as a multiple of g_{n}.

4 Structure of this International Standard

4.1 General

Clauses on the electrodynamic vibration generator, power amplifier and system as a whole include subclauses giving information that the specification writer may include in his relevant specification for the acquisition of a complete system or for components of a system.

A single relevant specification is unlikely to include all of the subclauses. For example, if only an amplifier is to be acquired, some of the system subclauses are not necessary, and only a few of the vibrator subclauses are needed for interface information. It is suggested that the writer of a specification read the entire standard before selecting the subclauses needed for a particular application.

4.2 Subclause coding

A code appears after the title of each subclause as an aid to the reader and to the writer of relevant specifications. This code has the form **(X,y)**.

The entry at position **X** specifies the type of acquisition for which the subclause is applicable:

- **A** for all acquisitions,
- **S** only for system acquisitions, and