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Methods for the calibration of vibration and shock transducers – Part 15: Primary angular vibration calibration by laser interferometry (ISO 16063-15:2006, IDT)

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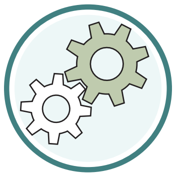

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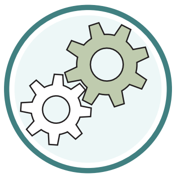

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Den internationella standarden ISO 16063-15:2006 gäller som svensk standard. Detta dokument innehåller den officiella engelska versionen av ISO 16063-15:2006.

The International Standard ISO 16063-15:2006 has the status of a Swedish Standard. This document contains the official version of ISO 16063-15:2006.

Upplysningar om sakinnehållet i standarden lämnas av SIS, Swedish Standards Institute, telefon 08-555 520 00. Standarder kan beställas hos SIS som även lämnar allmänna upplysningar om svensk och utländsk standard.

Information about the content of the standard is available from the Swedish Standards Institute (SIS), telephone +46 8 555 520 00. Standards may be ordered from SIS, who can also provide general information about Swedish and foreign standards.

Denna standard är framtagen av kommittén för Maskiners påverkan av vibrationer, SIS/TK 111/AG 02.

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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 16063-15 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 3, *Use and calibration of vibration and shock measuring instruments*.

ISO 16063 consists of the following parts, under the general title *Methods for the calibration of vibration and shock transducers*:

— *Part 1: Basic concepts*

— *Part 11: Primary vibration calibration by laser interferometry*

— *Part 12: Primary vibration calibration by the reciprocity method*

— *Part 13: Primary shock calibration using laser interferometry*

— *Part 15: Primary angular vibration calibration by laser interferometry*

— *Part 21: Vibration calibration by comparison to a reference transducer*

— *Part 22: Shock calibration by comparison to a reference transducer*

The following additional parts are under preparation:

— *Part 23, addressing the angular vibration calibration by comparison to reference transducers*

— *Part 31, addressing the testing of transverse vibration sensitivity*

— *Part 32, addressing the resonance testing*

— *Part 41, addressing the calibration of laser vibrometers*

— *Part 42, addressing the calibration of seismometers*

Methods for the calibration of vibration and shock transducers —

Part 15: Primary angular vibration calibration by laser interferometry

1 Scope

This part of ISO 16063 specifies the instrumentation and procedures used for primary angular vibration calibration of angular transducers, i.e. angular accelerometers, angular velocity transducers and rotational angle transducers (with or without amplifier) to obtain the magnitude and the phase shift of the complex sensitivity by steady-state sinusoidal vibration and laser interferometry. The methods specified in this part of ISO 16063 are applicable to measuring instruments (rotational laser vibrometers in particular) and to angular transducers as defined in ISO 2041 for the quantities of rotational angle, angular velocity and angular acceleration.

It is applicable to a frequency range from 1 Hz to 1,6 kHz and a dynamic range (amplitude) from 0,1 rad/s^2 to 1 000 rad/s^2 (frequency-dependent).

These ranges are covered with the uncertainty of measurement specified in Clause 3. Calibration frequencies lower than 1 Hz (e.g. 0,4 Hz, which is a reference frequency used in other International Standards) and angular acceleration amplitudes smaller than 0,1 rad/s^2 can be achieved using method 3A or method 3B specified in this part of ISO 16063, in conjunction with an appropriate low-frequency angular vibration generator.

Method 1A (cf. Clause 8: fringe-counting, interferometer type A) and method 1B (cf. Clause 8: fringe-counting, interferometer type B) are applicable to the calibration of the magnitude of complex sensitivity in the frequency range of 1 Hz to 800 Hz and under special conditions, at higher frequencies. Method 2A (cf. Clause 9: minimum-point method, interferometer type A) and method 2B (cf. Clause 9: minimum-point method, interferometer type B) can be used for sensitivity magnitude calibration in the frequency range of 800 Hz to 1,6 kHz. Method 3A (cf. Clause 10: sine-approximation method, interferometer type A) and method 3B (cf. Clause 10: sine-approximation method, interferometer type B) can be used for magnitude of sensitivity and phase calibration in the frequency range of 1 Hz to 1,6 kHz. Methods 1A, 1B and 3A, 3B provide for calibrations at fixed angular acceleration amplitudes at various frequencies. Methods 2A and 2B require calibrations at fixed rotational angle amplitudes (angular velocity amplitude and angular acceleration amplitude vary with frequency).

NOTE 1 The numbering 1 to 3 of the methods characterizes the handling of the interferometer output signal(s) analogous to ISO 16063-11: number 1 for fringe counting, number 2 for minimum-point detection and number 3 for sine-approximation. Each of these signal handling procedures can be used together with interferometer types A and B specified in this part of ISO 16063.

Interferometer type A designates a Michelson or Mach-Zehnder interferometer with retro-reflector(s) located at a radius, R, from the axis of rotation of the angular exciter. This interferometer type is limited to rotational angle amplitudes of 3° maximum. Interferometer type B designates a Michelson or a Mach-Zehnder interferometer using a circular diffraction grating implemented on the lateral surface of the circular measuring table. This interferometer type is not limited as regards the rotational angle amplitude if the diffraction grating covers the whole lateral surface of the disk (i.e. 360°). Usually, the maximum angular vibration is, in this case, limited by the angular vibration exciter.

NOTE 2 Though the calibration methods specified in this part of ISO 16063 are applicable to angular transducers (according to definition in ISO 2041) and, in addition, to measuring instrumentation for angular motion quantities, the specifications are given for transducers as calibration objects, for the sake of simplified description. Some specific information for the calibration of rotational laser vibrometers is given in 4.11 and Figure 11.

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 266, *Acoustics — Preferred frequencies*

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

ISO 16063-1:1998, *Methods for the calibration of vibration and shock transducers — Part 1: Basic concepts*

3 Uncertainty of measurement

The limits of the uncertainty of measurement applicable to this part of ISO 16063 shall be as follows:

a) for the magnitude of sensitivity:

— 0,5 % of the measured value at reference conditions,

— $\leqslant$ 1 % of the measured value outside reference conditions;

b) for the phase shift of sensitivity:

— 0,5° of the measured value at reference conditions,

— $\leqslant$ 1° of the reading outside reference conditions.

Recommended reference conditions are as follows:

— frequency: 160 Hz, 80 Hz, 40 Hz, 16 Hz or 8 Hz (or radian frequency, ω: 1 000 rad/s, 500 rad/s, 250 rad/s, 100 rad/s or 50 rad/s);

— angular acceleration: (angular acceleration amplitude or r.m.s. value): 100 rad/s^2, 50 rad/s^2, 20 rad/s^2, 10 rad/s^2, 5 rad/s^2, 2 rad/s^2 or 1 rad/s^2.

Amplifier settings shall be selected for optimum performance with respect to noise, distortion and influence from cut-off frequencies.

The uncertainty of measurement is expressed as the expanded measurement uncertainty in accordance with ISO 16063-1, for the coverage factor $k = 2$ (referred to, in short, as “uncertainty”).

4 Requirements for apparatus

4.1 General

Clause 4 gives recommended specifications for the apparatus necessary to comply with the scope of Clause 1 and to obtain the uncertainties of Clause 3.

If desired, systems covering only parts of the ranges may be used, and normally different systems (e.g. exciters) should be used to cover all the frequency and dynamic ranges.

NOTE The apparatus specified in Clause 4 covers all devices and instruments required for any of the six calibration methods described in this part of ISO 16063. The assignment to a particular method is indicated (cf. Figures 2, 3, 4, 5, 6, 7, 8 and 10).

4.2 Frequency generator and indicator

A frequency generator and indicator having the following characteristics shall be used:

a) uncertainty of frequency: maximum 0,05 % of reading;

b) frequency stability: better than ± 0,05 % of reading over the measurement time;

c) amplitude stability: better than ± 0,05 % of reading over the measurement time.

4.3 Power amplifier/angular vibration exciter combination

4.3.1 General

A power amplifier/angular vibration exciter combination having the following characteristics shall be used:

a) total harmonic distortion: 2 % maximum;

NOTE 1 This specification relates to the input quantity for the transducer to be calibrated.

NOTE 2 If method 3A or method 3B is used, greater harmonic distortions can be tolerable.

b) transverse, and rocking angular acceleration: sufficiently small to prevent excessive effects on the calibration results. For interferometer type A, a transverse motion of less than 1 % of the tangential motion component at the minimum rotational angle displacement can be required. For interferometer type B, a maximum lateral motion (including eccentricity) of 2 µm is tolerated, which can be achieved only if the moving part (measuring table) of the angular exciter is carried in a high-precision rotational air bearing;

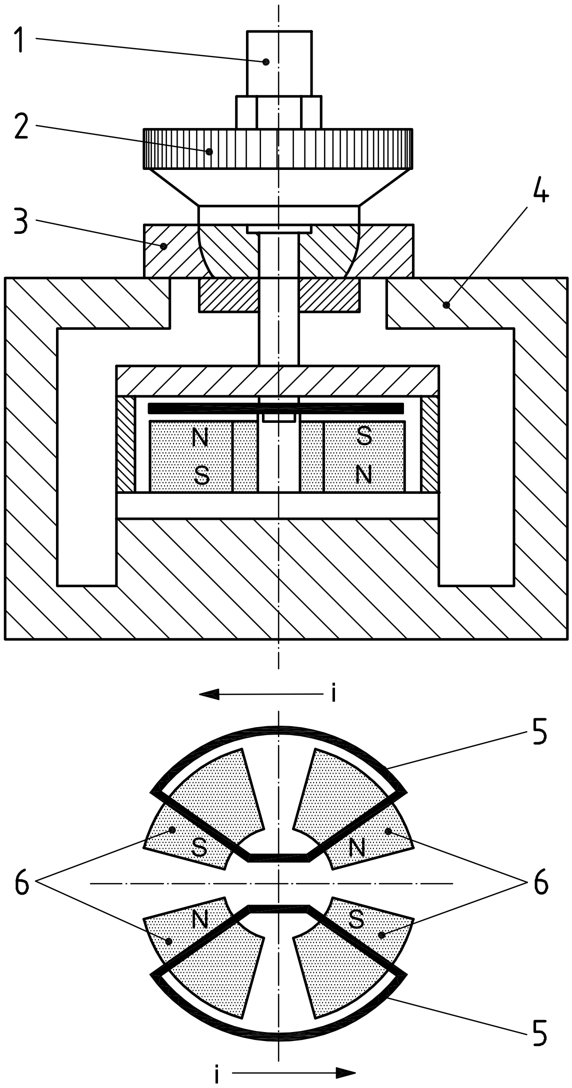
c) hum and noise: 70 dB minimum below full output;

d) stability of angular acceleration amplitude: better than ± 0,05 % of reading over the measurement period.

4.3.2 Electro-dynamic angular vibration exciter

An electrodynamic vibration exciter is based on the Lorentz force acting on electric charge carriers when these move through a magnetic field.

In analogy to common electrodynamic vibration exciters designed to generate rectilinear vibration, the coil located in the magnetized air gap of a magnetic circuit can be so designed that the Lorentz force generates a dynamic torque exciting the measuring table with the angular transducer to be calibrated to angular vibration. In the working frequency range (i.e. 1 Hz to 1,6 kHz), the amplitude of angular acceleration is proportional to the amplitude of the electric current carried through the coil. An example of an angular vibration exciter is shown in Figure 1. The maximum rotational amplitude is in this case limited to 30° (i.e. double amplitude: 1 rad). Another example of an angular acceleration exciter (amplitude of 60°, i.e. 1 rad) is described in Reference [14].



Key

1 angular accelerometer
2 diffraction grating
3 air bearing
4 housing
5 coil
6 magnet

Figure 1 — Example of an angular exciter (mode of function)

4.3.3 Angular vibration exciter based on a brushless electric motor

Special angular exciters have been designed and manufactured for angular transducer calibration using commercial electric motors.

For the testing of inertial navigation sensors, so-called “rate tables” have been developed for many years. These are often equipped with brushless, three-phase, hollow-shaft motors that are electronically commutated and servo-controlled, in particular for the angular velocity, i.e. angular rate operating mode. Normally, a constant angular velocity is generated. Often, sinusoidal angular velocities with low distortion are achieved.

The progress in control made over the last few years allows this exciter type to be used even to generate angular acceleration. A basic requirement is the use of an air bearing as in the flat-coil exciter (cf. 4.3.2).

As the distortion increases after differentiation, the calibration of angular accelerometers can require a frequency-selective measurement of the transducer output signal, which is ensured by the use of method 3A or 3B (i.e. sine-approximation).

4.4 Seismic block(s) for vibration exciter and laser interferometer

The angular vibration exciter and the interferometer shall be mounted on the same heavy block or on two different heavy blocks so as to prevent relative motion due to ground motion, or to prevent the reaction of the vibration exciter's support structure from excessively influencing the calibration results.

When a common seismic block is used, this should have a moment of inertia at least 2 000 times that of the moving mass. This causes less than 0,05 % reactive angular vibration of angular transducer and interferometer. If the moment of inertia of the seismic block is smaller, its motion generated by the vibrator shall be taken into account.

To suppress disturbing effects of ground motion, the seismic block(s) used in the frequency range of 1 Hz to 1,6 kHz should be suspended on damped springs designed to reduce the uncertainty component due to these effects to less than 0,1 %.

4.5 Laser

A laser of the red helium-neon type or a single-frequency laser with another wavelength of known value shall be used. Under laboratory conditions (i.e. at an atmospheric pressure of 100 kPa, a temperature to 23 °C and a relative humidity of 50 %), the wavelength of a red helium-neon laser is 0,632 81 µm.

If the laser is provided with a manual or automatic atmospheric compensation device, this shall be set to zero or switched off.

4.6 Interferometer

4.6.1 General

The interferometer may be used to transform

— the rotational angle, $\Phi(t)$, into a proportional phase shift, $\varphi_M(t)$, of the interferometer output signal,

— the angular velocity, $\Omega(t)$, into a proportional frequency shift, $f_D(t)$ (Doppler frequency), of the interferometer output signal.

For both transformations, a homodyne or a heterodyne interferometer (cf. Figures 3 to 8 and 10) and a one-channel or two-channel arrangement (cf. Figures 3 to 8 and 10) may be used.

The first transformation of $\Phi(t)$ into $\varphi_M(t)$ is specified in this part of ISO 16063 as a standard procedure whereas the latter transformation of $\Omega(t)$ into $f_D(t)$ is given as an option with reference to detailed descriptions in the literature.

The interferometer types A and B basically have in common that the measuring beam senses a translational displacement motion component so that an interferometer arrangement designed for rectilinear vibration measurements can be used. To make the application of such conventional interferometers possible, the quantity of rotational motion to be measured is converted into a representative translational displacement motion component using retro-reflector(s) as measuring reflector(s) for interferometer type A, and a diffraction grating arranged on the rotary measuring table for interferometer type B. In the latter case, an optically reflecting diffraction grating is to be arranged on the lateral surface of an air-borne rotary table to meet the requirement of the tolerable eccentricity of 2 µm.