INTERNATIONAL STANDARD

ISO 5349-1

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Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration —

Part 1: General requirements

Vibrations mécaniques — Mesurage et évaluation de l'exposition des individus aux vibrations transmises par la main —

Partie 1: Exigences générales

Reference number
ISO 5349-1:2001(E)

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

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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 3.

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 part of ISO 5349 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 5349-1 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 4, *Human exposure to mechanical vibration and shock*.

This first edition of ISO 5349-1 cancels and replaces ISO 5349:1986, of which it constitutes a technical revision. It is, in most respects, compatible with its predecessor, but differs from it technically in several important respects.

In the previous version, the evaluation of vibration exposure was based on the directional component with the greatest frequency-weighted root-mean-square acceleration. In the present version, the evaluation is based on the "vibration total value", i.e. the root-sum-of-squares of the three frequency-weighted root-mean-square component values. This change recognizes the fact that the vibration characteristics of some power tool types are not dominated by a single directional component.

Vibration exposures based on the root-sum-of-squares method will have values greater than those reported for a single direction of vibration. Measurement of vibration in three axes will result in a vibration total value of up to 1,7 times (typically between 1,2 and 1,5 times) the magnitude of the greatest component. For data obtained in accordance with ISO 5349:1986, the vibration total value can be calculated from the three component values as shown in 4.5 of this part of ISO 5349. Where only the greatest single-axis value is available, the vibration total value shall be estimated from this value using a suitable multiplying factor as discussed in 4.5.

The daily vibration exposure in accordance with this part of ISO 5349 is based on the 8-h energy-equivalent acceleration value. The previous version used a reference duration of 4 h. The change to the more conventional 8-h reference duration brings the evaluation of vibration exposure into line with the "time-weighted average" procedures commonly used for the evaluation of human exposures to noise and to chemical substances. The use of the 8-h reference duration is purely a matter of convention and does not imply that a "typical" daily exposure duration is 8 h. Conversion of 4-h equivalent magnitudes to 8-h values is achieved easily, by applying a multiplying factor of 0,7.

The frequency weighting previously had a slope of zero at frequencies below 16 Hz and –6 dB per octave at higher frequencies and applied over the frequency range covered by the octave bands from 8 Hz to 1 000 Hz. It is now defined mathematically in annex A as a realizable filter characteristic, designated W_h. Band-limiting filters are also defined with cut-off frequencies of 6,3 Hz and 1 250 Hz. The one-third-octave band weighting factors, also given in annex A, differ slightly from those in the previous version in that they describe the W_h curve with band-limiting included.

The guidance in annex C on the relationship between vibration exposure and the development of vascular symptoms, is broadly compatible with that in annex A of the previous version, but is restricted to consideration of a prevalence of 10 % in order to limit the potential for inappropriate use of the relationship. Compared to the previous version, daily vibration exposures are now expressed as 8-h energy-equivalent values and the values quoted have been multiplied by a factor of 1,4 to estimate the increase resulting from the change from evaluation using the greatest single-axis value to evaluation using the vibration total value.

International Standard ISO 5349 consists of the following parts, under the general title *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration*:

Part 1: General requirements

Part 2: Practical guidance for measurement at the workplace

Annex A forms a normative part of this part of ISO 5349. Annexes B to F are for information only.

Introduction

Intensive vibration can be transmitted to the hands and arms of operators from vibrating tools, vibrating machinery or vibrating workpieces. Such situations occur, for example, when a person handles tools such as pneumatic, electric, hydraulic or internal combustion engine-driven chain saws, percussive tools or grinders.

Depending on the type and place of work, vibration can enter one arm only, or both arms simultaneously, and may be transmitted through the hand and arm to the shoulder. The vibration of body parts and the perceived vibration are frequently a source of discomfort and possibly reduced proficiency. Continued, habitual use of many vibrating power tools has been found to be connected with various patterns of diseases affecting the blood vessels, nerves, bones, joints, muscles or connective tissues of the hand and forearm.

The vibration exposures required to cause these disorders are not known precisely, neither with respect to vibration magnitude and frequency spectrum, nor with respect to daily and cumulative exposure duration. The guidance given in this part of ISO 5349 is derived from limited quantitative data available from both practical experience and laboratory experimentation concerning human response to hand-transmitted vibration, and on limited information regarding current exposure conditions. It is thus difficult to propose a comprehensive method for the evaluation of vibration exposure. However, the use of the information given in this part of ISO 5349 should protect the majority of workers against serious health impairment associated with hand-transmitted vibration. It may also assist in the development of new hand-operated power tools to reduce the risk of vibration-related health effects. It does not define safe exposure ranges in which vibration diseases cannot occur.

The use of this part of ISO 5349 will contribute to the gathering of consistent data in order to improve occupational safety. In particular, it is hoped that such data will serve to extend the present knowledge of dose-effect relationships.

This part of ISO 5349 specifies the general requirements for the measurement and evaluation of human exposure to hand-transmitted vibration. It is supplemented by the information given in ISO 5349-2, which gives practical guidance for the implementation of appropriate measurement and evaluation techniques at the workplace. Instrumentation to be used for measurements made in accordance with ISO 5349 is fully specified in ISO 8041.

Annex A contains definitions for the frequency weighting W_h and for band-limiting filters, required for measurement of frequency-weighted acceleration in accordance with ISO 5349.

Annex B contains information on the health effects of hand-transmitted vibration, while annex C gives guidance which may assist competent authorities responsible for the definition of exposure limits or action levels as required. Annex D contains information on other factors which can affect human response to hand-transmitted vibration and annex E contains guidance on preventive measures for those responsible for occupational health and safety.

To facilitate further progress in this field and to allow the quantitative comparison of exposure data, uniform methods for measuring and reporting exposure of human beings to hand-transmitted vibration are desirable. Further information is contained in annex F.

Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration —

Part 1: General requirements

1 Scope

This part of ISO 5349 specifies general requirements for measuring and reporting hand-transmitted vibration exposure in three orthogonal axes. It defines a frequency weighting and band-limiting filters to allow uniform comparison of measurements. The values obtained can be used to predict adverse effects of hand-transmitted vibration over the frequency range covered by the octave bands from 8 Hz to 1 000 Hz.

This part of ISO 5349 is applicable to periodic and to random or non-periodic vibration. Provisionally, this part of ISO 5349 is also applicable to repeated shock type excitation (impact).

NOTE 1 The time dependency for human response to repeated shocks is not fully known. Application of this part of ISO 5349 for such vibration is to be made with caution.

This part of ISO 5349 provides guidance for the evaluation of hand-transmitted vibration exposure, specified in terms of a frequency-weighted vibration acceleration and daily exposure time. It does not define limits of safe vibration exposure.

NOTE 2 Annex C is concerned with the approximate relative importance of various characteristics of the vibration exposure which are believed to produce health effects.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 5349. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 5349 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 2041, *Vibration and shock — Vocabulary.*

ISO 5349-2, *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 2: Practical guidance for measurement at the workplace.*

ISO 8041, *Human response to vibration — Measuring instrumentation.*

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

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this part of ISO 5349, the terms and definitions given in ISO 2041 apply.

NOTE For the convenience of users of this part of ISO 5349, a glossary of terms relating to medical conditions is given in annex B.

3.2 Symbols

In this part of ISO 5349, the following symbols are used.

$a_{hw}(t)$ instantaneous single-axis acceleration value of the frequency-weighted hand-transmitted vibration at time t, in metres per second squared (m/s^2);

a_{hw} root-mean-square (r.m.s.) single-axis acceleration value of the frequency-weighted hand-transmitted vibration, in metres per second squared (m/s^2);

a_{hwx}, a_{hwy}, a_{hwz} values of a_{hw}, in metres per second squared (m/s^2), for the axes denoted x, y and z respectively;

a_{hv} vibration total value of frequency-weighted r.m.s. acceleration (sometimes known as the vector sum or the frequency-weighted acceleration sum); it is the root-sum-of-squares of the a_{hw} values for the three measured axes of vibration, in metres per second squared (m/s^2);

$a_{hv(eq,8h)}$ daily vibration exposure (8-h energy-equivalent vibration total value), in metres per second squared (m/s^2);

$A(8)$ a convenient alternative term for the daily vibration exposure $a_{hv(eq,8h)}$;

D_y group mean total (lifetime) exposure duration, in years;

T total daily duration of exposure to the vibration a_{hv};

T_0 reference duration of 8 h (28 800 s);

W_h frequency-weighting characteristic for hand-transmitted vibration.

4 Characterization of hand-transmitted vibration

4.1 General considerations

The method specified in this part of ISO 5349 takes account of the following factors which are known to influence the effects of human exposure to hand-transmitted vibration in working conditions:

a) the frequency spectrum of vibration;

b) the magnitude of vibration;

c) the duration of exposure per working day;

d) the cumulative exposure to date.

Other factors which may influence the effects of vibration exposure, but for which standardized methods for reporting do not yet exist, are listed in annex D.

4.2 Measuring equipment for hand-transmitted vibration

4.2.1 General

Measurement of hand-transmitted vibration shall be undertaken using instrumentation conforming to the requirements of ISO 8041. This equipment shall be checked for correct operation before and after use. The calibration shall be traceable to a recognized standard maintained by an accredited laboratory.

4.2.2 Vibration transducers

The vibration transducer may be an accelerometer which may be designed to make general vibration measurements (for non-percussive tools) or may be specifically designed for large peak accelerations such as those produced by percussive tools.

The vibration transducers shall be able to withstand the range of vibration magnitudes and shall have stable characteristics. The dimensions of the transducers shall be such that they do not interfere with the operation of the machine and such that the location of the point of measurement can be identified.

ISO 5349-2 contains further guidance on the selection of transducers.

4.2.3 Location and orientation of transducers

The vibration transmitted to the hand shall be measured and reported for three directions of an orthogonal coordinate system such as defined in Figure 1.

For practical vibration measurements, the orientation of the coordinate system may be defined with reference to an appropriate basicentric coordinate system (see Figure 1) originating, for example, in a vibrating appliance, workpiece, handle or control device gripped by the hand (see ISO 8727 for further information).

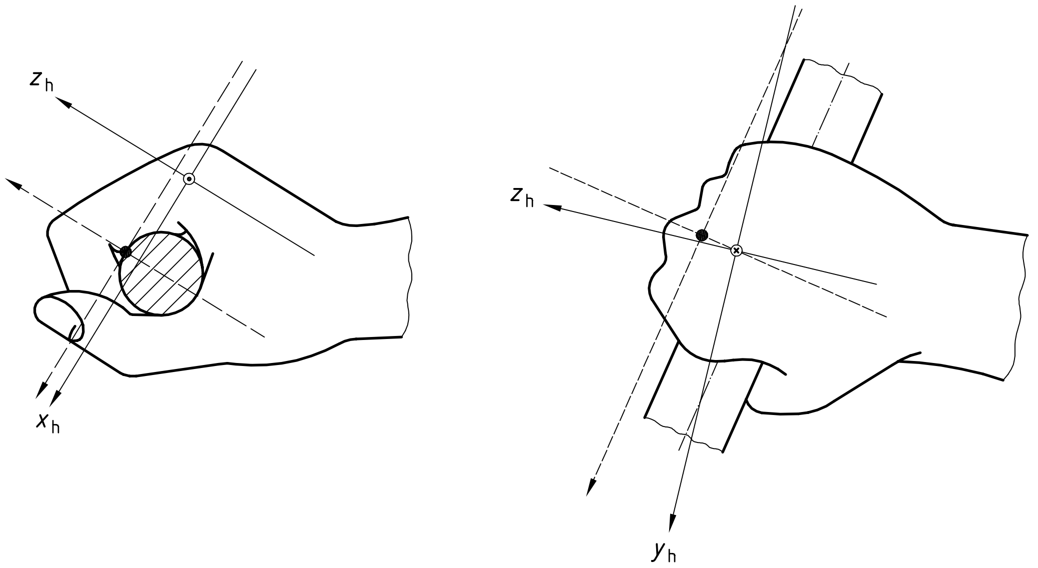
The vibration in the three directions should preferably be measured simultaneously. Measurements made sequentially along each of the three axes are acceptable, provided the operating conditions are similar for all three measurements. The measurements shall be made on the vibrating surface as close as possible to the centre of the gripping zone of the machine, tool or workpiece. The location of the transducers shall be reported.

NOTE The vibration magnitude can vary considerably with position on the vibrating surface.

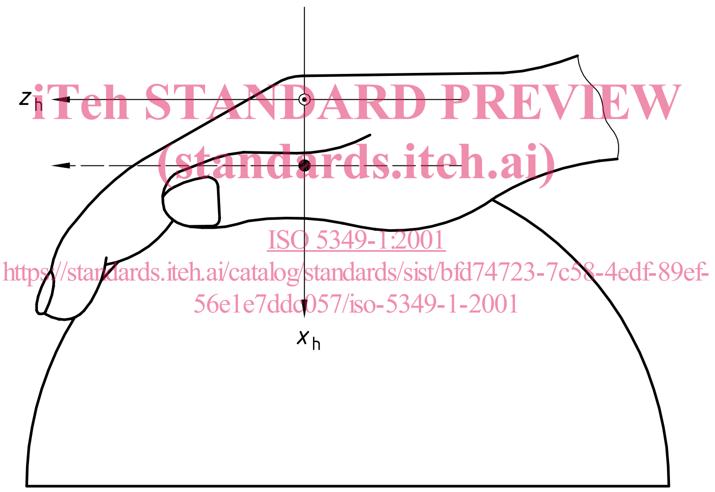
Further guidance on transducer positioning is given in ISO 5349-2.

4.2.4 Mounting of transducers

The transducers should be mounted rigidly. Further information on accelerometer mounting is given in ISO 5348 and ISO 5349-2. Practical guidance on mounting transducers in difficult situations (such as on resilient surfaces or where the vibration is impulsive), and on the use of hand-held adaptors, is also given in ISO 5349-2.



a) "Handgrip" position (In this position, the hand adopts a standardized grip on a cylindrical bar)



Key

————————	Biodynamic coordinate system
---------------	Basicentric coordinate system

b) "Flat palm" position (In this position, the hand presses down onto a sphere)

NOTE The origin of the biodynamic coordinate system is the head of the third metacarpal (distal extremity). The z_h-axis (i.e. hand axis) is defined as the longitudinal axis of the third metacarpal bone and is oriented positively towards the distal end of the finger. The x_h-axis passes through the origin, is perpendicular to the z_h-axis, and is positive in the forwards direction when the hand is in the normal anatomical position (palm facing forwards). The y_h-axis is perpendicular to the other two axes and is positive in the direction towards the fifth finger (thumb). In practice, the basicentric coordinate system is used: the system is generally rotated in the y-z plane so that the y_h-axis is parallel to the handle axis.

Figure 1 — Coordinate systems for the hand

4.3 Coupling of the hand to the vibration source

Although characterization of the vibration exposure currently uses the acceleration of the surface in contact with the hand as the primary quantity, it is reasonable to assume that the biological effects depend to a large extent on the coupling of the hand to the vibration source. It should also be noted that the coupling can affect considerably the vibration magnitudes measured.

The vibration measurements shall be made with forces which are representative of the coupling of the hand to the vibrating power tool, handle or workpiece in typical operation of the tool or process.

Forces between the hand and gripping zone should be measured and reported.[1)] It is also recommended that a description of the operator's posture be reported for individual conditions and/or operating procedures (see annexes D and F).

4.4 Quantity to be measured

The primary quantity used to describe the magnitude of the vibration shall be the root-mean-square (r.m.s.) frequency-weighted acceleration expressed in metres per second squared (m/s^2).

The measurement of frequency-weighted acceleration requires the application of a frequency weighting and band-limiting filters. The frequency weighting W_h reflects the assumed importance of different frequencies in causing injury to the hand. The characteristics of the W_h frequency weighting and methods for band-limiting are given in annex A.

The r.m.s. value shall be measured using a linear integration method. The integration time shall be chosen such that a representative sample of the vibration signal is used (see ISO 5349-2).

For additional purposes (research, prevention, technical reduction of vibration) it is strongly recommended that frequency spectra be obtained (see annex F for further information).

4.5 Multi-axis vibration

It is known that on most power tools the vibration entering the hand contains contributions from all three measurement directions. It is assumed that vibration in each of the three directions is equally detrimental. Measurements should therefore be made for all three directions. The frequency-weighted r.m.s. acceleration values for the x-, y- and z-axes, a_{hwx}, a_{hwy} and a_{hwz}, shall be reported separately (see annex F).

The evaluation of vibration exposure (see clause 5), however, is based on a quantity that combines all three axes. This is the vibration total value, a_{hv}, and is defined as the root-sum-of-squares of the three component values:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2} \quad (1)$$

In some cases it may not be possible to make vibration measurements in three axes. If measurements are made only in one or two axes, the axis of greatest vibration shall be included (where this can be identified). The vibration total value shall be estimated using the measured values available and a carefully considered multiplying factor. The vibration magnitude in the axis of greatest vibration requires a multiplying factor in the range 1,0 to 1,7 to give the vibration total value (for further advice, see ISO 5349-2). Where a multiplying factor is used to estimate the vibration total value, the multiplying factor and a justification for the choice of value shall be reported, together with the component value(s) measured.

1) An International Standard on the measurement of gripping and pushing forces is in course of preparation.

5 Characterization of hand-transmitted vibration exposure

5.1 General

Vibration exposure is dependent on the magnitude of the vibration and on the duration of the exposure. In order to apply the guidance on health effects given in annex C, the vibration magnitude is represented by the vibration total value a_{hv}.

5.2 Daily exposure duration

Daily exposure duration is the total time for which the hand(s) is(are) exposed to vibration during the working day. The vibration exposure time may be shorter than the time for which the person is working with the power tools or workpieces. It is important to base estimates of total daily exposure duration on appropriate representative samples for the various operating conditions and durations and their intermittency (see ISO 5349-2 for further guidance).

5.3 Daily vibration exposure

Daily vibration exposure is derived from the magnitude of the vibration (vibration total value) and the daily exposure duration.

In order to facilitate comparisons between daily exposures of different durations, the daily vibration exposure shall be expressed in terms of the 8-h energy-equivalent frequency-weighted vibration total value, $a_{hv(eq,8h)}$, as shown in equation (2). For convenience, $a_{hv(eq,8h)}$ is denoted $A(8)$:

$$A(8) = a_{hv}\sqrt{\frac{T}{T_0}} \tag{2}$$

where

T is the total daily duration of exposure to the vibration a_{hv};

T_0 is the reference duration of 8 h (28 800 s).

If the work is such that the total daily vibration exposure consists of several operations with different vibration magnitudes, then the daily vibration exposure, $A(8)$, shall be obtained using equation (3):

$$A(8) = \sqrt{\frac{1}{T_0}\sum_{i=1}^{n} a_{hvi}^2 T_i} \tag{3}$$

where

a_{hvi} is the vibration total value for the i th operation;

n is the number of individual vibration exposures;

T_i is the duration of the i th operation.

The individual contributions to $A(8)$ shall be reported separately.

EXAMPLE If the vibration total values for exposure times of 1 h, 3 h and 0,5 h (within the same working day) are 2 m/s², 3,5 m/s² and 10 m/s² respectively, then:

$$A(8) = \sqrt{\frac{1}{8\ \text{h}}\left[\left(2\ \text{m/s}^2\right)^2 \times 1\ \text{h} + \left(3{,}5\ \text{m/s}^2\right)^2 \times 3\ \text{h} + \left(10\ \text{m/s}^2\right)^2 \times 0{,}5\ \text{h}\right]} = 3{,}4\ \text{m/s}^2$$