# INTERNATIONAL STANDARD

# ISO 5349-2

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

## Part 2:
## Practical guidance for measurement at the workplace



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

*Partie 2: Guide pratique pour le mesurage sur le lieu de travail*



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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.

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 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 5349-2 was prepared by the European Committee for Standardization (CEN) in collaboration with Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 4, *Human exposure to mechanical vibration and shock*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).



Throughout the text of this document, read "...this European Standard..." to mean "...this 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*

Annexes A to E of this part of ISO 5349 are for information only.

## Contents





 

## Foreword

The text of EN ISO 5349-2:2001 has been prepared by Technical Committee CEN/TC 231 "Mechanical vibration and shock", the secretariat of which is held by DIN, in collaboration with Technical Committee ISO/TC 108 "Mechanical vibration and shock".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by February 2002, and conflicting national standards shall be withdrawn at the latest by February 2002.

Users of this EN, prepared in the field of application of Article 137 (formerly 118a) of the EC Treaty, should be aware that standards have no formal legal relationship with Directives which may have been made under Article 137 of the Treaty. In addition, national legislation in the Member states may contain more stringent requirements than the minimum requirements of a Directive based on Article 137. Information on the relationship between the national legislation implementing Directives based on Article 137 and this EN may be given in a national foreword of the national standard implementing this EN.

Annexes A to E of this European Standard are informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

# Introduction

Operating machinery may expose workers to hand-transmitted mechanical vibration which can interfere with comfort, working efficiency and, in some circumstances, health and safety. The general requirements for measuring and evaluating hand-transmitted vibration exposure are specified in ISO 5349-1. The aim of the present part of ISO 5349 is to provide practical guidelines in accordance with ISO 5349-1 to perform measurements correctly and to develop an effective strategy for measurement of hand-transmitted vibration at the workplace.

The use of the strategy described in this part of ISO 5349 will lead to a realistic picture of the daily exposure of the operator at the workplace and of the relevant uncertainties.

The evaluation of vibration exposure can be broken up into a number of distinct stages:

– identifying a series of discrete operations which make up the subject's normal working pattern;

– selection of operations to be measured;

– measuring the r.m.s. acceleration value for each selected operation;

– evaluation of the typical daily exposure time for each operation identified;

– calculating the 8-h energy-equivalent vibration total value (daily vibration exposure).



The evaluation of vibration exposure as described in ISO 5349-1 is solely based on the measurement of vibration magnitude at the grip zones or handles and exposure times. Additional factors, such as gripping and feed forces applied by the operator, the posture of the hand and arm, the direction of the vibration and the environmental conditions, etc. are not taken into consideration. This part of ISO 5349, being an application of ISO 5349-1, does not define guidance to evaluate these additional factors. However, it is recognized that reporting of all relevant information is important for the development of improved methods for the assessment of vibration risk.



 

## 1 Scope

This part of ISO 5349 provides guidelines for the measurement and evaluation of hand-transmitted vibration at the workplace in accordance with ISO 5349-1.

This part of ISO 5349 describes the precautions to be taken to make representative vibration measurements and to determine the daily exposure time for each operation in order to calculate the 8-h energy-equivalent vibration total value (daily vibration exposure). This part of ISO 5349 provides a means to determine the relevant operations which should be taken into account when determining the vibration exposure.

This part of ISO 5349 applies to all situations where people are exposed to vibration transmitted to the hand-arm system by hand-held or hand-guided machinery, vibrating workpieces, or controls of mobile or fixed machinery.

## 2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

ISO 2041, *Vibration and shock – Vocabulary*.

ISO 5349-1:2001, *Mechanical vibration – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 1: General requirements*.



ISO 5805, *Mechanical vibration and shock – Human exposure – Vocabulary*.

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



ISO 8662 (all parts), *Hand-held portable power tools – Measurement of vibrations at the handle*.

## 3 Terms and 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 and ISO 5805 and the following apply.

**3.1.1**
**hand-fed machine**
machine where the operator feeds workpieces to the working part of the machine, such that the vibration exposure is obtained through the hand-held workpiece

EXAMPLE band-saw, pedestal grinder

**3.1.2**
**hand-guided machine**
machine which is guided by the operator with his hands, such that the vibration exposure is obtained through the handles, steering wheel or tiller

EXAMPLE ride-on lawn mower, powered pallet truck, swing grinder

**3.1.3**
**hand-held workpiece**
workpiece which is held in the hand, such that vibration exposure is obtained through the hand-held workpiece rather than, or as well as, through the power tool handle

EXAMPLE casting held against a pedestal grinder, wood fed into a band-saw

**3.1.4**
**hand-held power tool**
powered tool which is held in the hand

EXAMPLE electric drill, pneumatic chisel, chain saw

**3.1.5**
**inserted tool**
interchangeable or replaceable attachment which fits into or onto a power tool or machine

EXAMPLE drill bit, chisel, chain saw chain, saw-blade, abrasive wheel

**3.1.6**
**operation**
identifiable task for which a representative vibration magnitude measurement is made, this may be for the use of a single power tool, or hand-held workpiece type or for a single phase of a task

**3.1.7**
**operator**
person using a hand-fed, hand-guided or hand-held machine or power tool

**3.1.8**
**tool operation**
any period during which a power tool is operating and the operator is being exposed to hand-transmitted vibration

**3.1.9**
**workpiece**
item being operated upon by a power tool



## 3.2 Symbols

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

$a_{hwi}$ single-axis root-mean-square (r.m.s.) value of the frequency-weighted hand-transmitted vibration for operation $i$, in m/s². An additional suffix x, y or z is used to indicate the direction of the measurement, i.e. $a_{hwix}$, $a_{hwiy}$ and $a_{hwiz}$

$a_{hvi}$ vibration total value (formerly denoted vector sum or frequency-weighted acceleration sum) for operation $i$ (root-sum-of-squares of the $a_{hwi}$ values for the three axes of vibration), in m/s²

$A(8)$ daily vibration exposure, in m/s²

$A_i(8)$ contribution of operation $i$ to the daily vibration exposure, in m/s² (for convenience, this is referred to as the "partial vibration exposure")

$T_0$ reference duration of 8 h (28800 s)

$T_i$ total duration (per day) of vibration exposure to operation $i$.

# 4 Quantities to be evaluated

There are two principal quantities to be evaluated for each operation *i* during exposure to vibration:

- the vibration total value $a_{hvi}$, expressed in metres per second squared (m/s²); this value is calculated from the three single-axis root-mean-square values of the frequency-weighted hand-transmitted vibration $a_{hwix}$, $a_{hwiy}$ and $a_{hwiz}$;
- the duration (per day) $T_i$ of vibration exposure to operation $i$.

The principal parameter to be reported is the daily vibration exposure $A(8)$. This is calculated from the values of $a_{hvi}$ and $T_i$ for all operations $i$ (see clause 8).

## 5 Preparation of the measurement procedure

### 5.1 General

The work of an operator at a workplace is composed of a series of operations, some of which may be repeated. The vibration exposure may vary greatly from one operation to another, either due to the use of different power tools or machines or different modes of operation of one power tool or machine.

To evaluate daily vibration exposure, it is first necessary to identify the operations which are likely to contribute significantly to the overall vibration exposure. For each of these operations, it is then necessary to decide on procedures for measuring the vibration exposure. The methods to be used will depend on the characteristics of the work environment, the work pattern and the vibration source.

### 5.2 Selection of operations to be measured

It is important to make measurements for all the power tools or workpieces which may give a significant contribution to the daily vibration exposure. To obtain a good picture of the average daily vibration exposure it is necessary to identify all

a) sources of vibration exposure (i.e. the machines and tools being used);

b) modes of operation of the power tool, e.g.:

   – chain saws may be idling, operating under load while cutting through a tree trunk, or operating under low load while cutting side branches,

   – a power drill may be used in impactive or non-impactive modes and may have a range of speed settings available;



c) changes in the operating conditions where this might affect vibration exposure, e.g.:

   – a road breaker being used initially on a hard concrete surface followed by use on the softer soil underneath,



   – a grinder being used initially for bulk metal removal followed by more intricate operations of cleaning and shaping;

d) inserted tools which might affect vibration exposure, e.g.:

   – a sander may be used with a series of different grades of abrasive paper, ranging from coarse to fine,

   – a stonemason may use a pneumatic chisel with a range of different chisel bits.

In addition, it can be useful to obtain

e) information from workers and supervisors on which situations they believe produce the highest vibration magnitude;

f) estimates of the potential vibration hazards for each operation, using information from manufacturers on vibration emission values, see annex A, or using published results of previous measurements on similar power tools.

### 5.3 Organization of the measurements

The organization of measurements can be approached in four basic ways:

a) Long-term measurement of continuous tool operation

   The operation time is long and continuous, and during this time the operator maintains contact with the vibrating surface. In this case the vibration measurement can be made over long periods during the normal use of the power tool. The operation may include changes in vibration magnitude, provided that they are part of the normal working procedure.

   In addition to vibration magnitude information, the evaluation of daily vibration exposure requires an evaluation of the duration of exposure to vibration per day.

 

b) Long-term measurement of intermittent tool operation

The operation time is long but includes short breaks where there is no vibration exposure, however, during the operation and breaks the operator maintains contact with the (vibrating) surface. In this case the vibration measurement can be made over long periods during the normal use of the power tool, provided that any breaks in operation are part of the normal working procedure and that the operator does not lose contact with the power tool or hand-held workpiece, or significantly alter position of his hands on the power tool or hand-held workpiece.

In addition to vibration magnitude information, the evaluation of daily vibration exposure requires an evaluation of the duration of exposure to the operation per day. In this case the duration of exposure to the operation includes the short breaks in vibration exposure and so will be longer than the duration of exposure to vibration.

c) Short-term measurement of intermittent tool operation

In many situations the hand is often taken off the power tool or hand-held workpiece, e.g. the power tool is put down, the hand is moved to a different part of the power tool, or another hand-held workpiece is picked up. In other situations, changes have to be made to the power tools being used, e.g. different abrasive belts or drill bits fitted or alternative power tools used. In these cases short-term measurements can only be made during each phase of the work operation.

In some cases it is difficult, or impossible, to get reliable measurements during the normal work process, due to the exposure durations being too short for measurement purposes. In this case measurements may be made during simulated work operations which artificially arrange longer uninterrupted exposures with work conditions as near to normal as possible.

In addition to vibration magnitude information, the evaluation of daily vibration exposure requires an evaluation of the exposure duration associated with each work phase.

d) Fixed-duration measurement of bursts of tool operation or single or multiple shocks

Some operations involve exposure to short-duration bursts of vibration exposure, this may be single or multiple shocks, such as riveting hammers, nail guns, etc., or bursts of exposure, such as powered impact wrenches. In such cases it is often difficult to make an evaluation of actual exposure times, although the number of bursts of vibration per day can be estimated. In this case measurements may be made over a fixed duration which includes one or more complete tool operations. The duration of measurement should include as little time before, between and after bursts of vibration as possible.



In addition to vibration magnitude information and the estimate of the number of bursts of vibration exposures per day, the evaluation of daily vibration exposure requires information on the measurement duration and the number of bursts of vibration during the measurement period.

NOTE 1 In the case of exposing the worker to multiple single shocks or transient vibration (e.g. fastening tools), the method described in ISO 5349-1 may not be adequate and underestimate the severity of shock exposure. However, in the absence of a better method, ISO 5349-1 may be applied but this should be done with caution and be indicated in the information to be reported.

NOTE 2 Where measurements of vibration magnitude are to be compared (e.g. to compare the vibration produced by two different power tool or inserted tool options) it is important to make measurements of continuous tool operation, i.e. with no breaks in vibration exposure.

## 5.4 Duration of vibration measurements

### 5.4.1 Measurement during normal working

A measurement should be an average over a period which is representative of the typical use of a power tool, machine or process. Where possible, the measurement period should start when the worker's hands first contact the vibrating surface, and should finish when the contact is broken. This period may include variations in the vibration magnitude and may even include periods when there is no exposure.

Where possible, a series of sample measurements should be taken at different times of the day, and averaged, so that variations in vibration through the day are accounted for.

NOTE The average vibration magnitude of a series of $N$ vibration magnitude samples is given by

 

$$a_{\text{hw}} = \sqrt{\frac{1}{T} \sum_{\text{j}=1}^{\text{N}} a_{\text{hwj}}^2 t_{\text{j}}}$$

where

$a_{\text{hwj}}$ is the measured vibration magnitude for sample j

$t_{\text{j}}$ is the measurement duration of sample j

$$T = \sum_{\text{j}=1}^{\text{N}} t_{\text{j}}$$

Vibration exposures are often for short periods, which are repeated many times during a working day. Although measurements can be averaged over complete cycles of operation (including periods when the vibration source is switched off), normally it is only possible to average over the short period that the hand is in contact with the vibrating surface.

The minimum acceptable duration of measurements depends on the signal, instrumentation and operation characteristics. The total measuring time (i.e. the number of samples multiplied by the duration per measurement) should be at least 1 min. A number of shorter duration samples should be taken in preference to a single long duration measurement. For each operation, at least three samples should be taken.

Measurements of very short duration (e.g. less than 8 s) are unlikely to be reliable, particularly in their evaluation of low-frequency components, and should be avoided where possible. Where very short duration measurements are unavoidable (e.g. certain types of pedestal grinding for which contact times can be very short), it is advisable to take many more than three samples to ensure a total sample time greater than 1 min.



### 5.4.2 Simulated work procedures

Where measurements are not possible, or difficult, during normal tool operation then simulated work procedures can be used to simplify the vibration measurement process.



The main use of simulated work procedures is to achieve measurements over longer periods than could be allowed during normal production work. For example, the pedestal grinding of small castings may only last a few seconds per casting; rather than try to measure for short durations on many castings it may be possible to simulate the grinding on a small number of scrap castings, using each scrap casting many times.

Picking up, putting down or replacing the power tool or hand-held workpiece may disturb the measurement. These disturbances may also be avoided by measuring during simulated work procedures which can be designed to avoid any interruptions between operations.

## 5.5 Estimation of daily vibration duration

The daily exposure duration for each vibration source shall be obtained. Often a typical daily vibration exposure time will be based on

- a measurement of the actual exposure time during a period of normal use (e.g. as evaluated over a complete work cycle, or during a typical 30 min period) and
- information on work rate (e.g. the number of work cycles per shift or the shift length).

The first of these will be a measurement to determine how long an operator is exposed to vibration, and from what source, during a specified period. Various techniques may be used, for example:

- use of a stopwatch;
- use of a dedicated data logger linked to power tool usage;
- analysis of video recordings;
- activity sampling.

 

The most reliable source of information on typical work rate is work records. However, it is important to ensure that the information is compatible with the information required for an evaluation of daily vibration exposure. For example, work records might give very accurate information on the number of completed work items at the end of each day, but where there is more than one operator, or unfinished work items at the end of a shift, this information may not be directly applicable to a vibration exposure evaluation.

Whichever method is used for vibration measurement, the total exposure time per day has to be found. Where the vibration has been averaged over a complete work cycle, the daily exposure time is simply the duration of the work cycle multiplied by the number of cycles per day. If a measurement has been made for a period while the hand is in contact with the vibrating surface, evaluate the total contact time per day.

**Warning!** In general, when operators are asked for information on their typical daily power tool usage, they will normally overestimate, giving an estimate of the period of time for which a power tool is used, including pauses in tool operation (e.g. breaks in tool operation between nuts when operating a nut runner or the time to prepare a new workpiece).

NOTE ISO 5349-1 only provides a system for evaluating daily vibration exposure on one working day; it cannot be assumed that the method provided by ISO 5349-1 can be extrapolated to allow the averaging of exposures over periods greater than one day. However, in some situations it may be desirable to obtain an evaluation of exposure based on exposure information obtained over periods greater than one day. For example, in some types of work the amount of time using vibrating power tools changes significantly from one day to the next (e.g. industries such as construction or ship building and repair); it is then difficult, or impossible, to use observation or work records to obtain an indication of typical daily exposure times. Annex B gives examples of methods which have been used for evaluating vibration exposures over periods greater than one day.

## 6 Measurement of vibration magnitude

### 6.1 Measurement equipment



#### 6.1.1 General

Vibration measurement systems generally use accelerometers to detect the motion of the vibrating surface. The vibration signal from the accelerometer can be processed in a number of different ways to achieve a measure of the frequency-weighted acceleration.



Vibration measurements may be made using simple, single-unit vibration meters, featuring built-in frequency weightings and integrating facilities. These systems are designed primarily to evaluate the vibration exposure at the workplace; they are generally sufficient for most situations covered by this part of ISO 5349. However, simple instrumentation may not be able to show errors associated with vibration measurement.

More sophisticated measurement systems are often based around some form of frequency analysis (e.g. one-third-octave or narrow band), they may use digital or analogue data recorders to store time information, they may use computer-based data acquisition and analysis techniques. These systems are more costly and complex to operate than the single-unit systems.

Where there is any doubt about the quality of the acceleration signal (e.g. DC-shift, see 6.2.4) it is useful to have information from frequency analysis. Frequency analysis will also provide information on any dominant frequencies, and harmonics, which may help to identify effective vibration control measures.

At the limits of application of ISO 5349-1 (e.g. repeated single shocks, dominant frequency components exceeding 1250 Hz) any additional information available e.g. from more sophisticated measurement systems may be useful.

Minimum performance requirements (e.g. frequency weighting characteristics, tolerances, dynamic range, sensitivity, linearity and overload capacity) for appropriate measuring and analysing equipment are given in ISO 8041.

#### 6.1.2 Accelerometers

##### 6.1.2.1 General

In general, the choice of accelerometer will be defined by the expected vibration magnitude, the required frequency range, the physical characteristics of the surface being measured and the environment in which they are to be used.

#### 6.1.2.2 Vibration magnitude

Hand-held machines can produce high vibration magnitudes. A pneumatic hammer, for example, may generate a maximum acceleration of 20000 m/s² to 50000 m/s². However, much of this energy is at frequencies well outside the frequency range used in this part of ISO 5349. The accelerometer chosen for the measurement has therefore to be able to operate at these very high vibration magnitudes and yet still respond to the much lower magnitudes in the frequency range from 6,3 Hz to 1250 Hz (one-third-octave band mid-frequencies). For the use of mechanical filters to suppress vibration at very high frequencies, see annex C.

#### 6.1.2.3 Frequency range

Accelerometer selection will also be influenced by the fundamental resonance frequency of the accelerometer, this is a characteristic of the accelerometer (it is sometimes referred to as the "mounted resonance frequency", "natural frequency" or "resonance frequency"). Information on the fundamental resonance frequency will be available from the accelerometer manufacturer. ISO 5348 recommends that the fundamental resonance frequency should be more than five times the maximum frequency of interest (for hand-transmitted vibration, this corresponds to 6250 Hz). For piezoelectric accelerometers, the fundamental resonance frequency should normally be much higher, ideally greater than 30 kHz, to minimize the likelihood of DC-shift distortion (see 6.2.4).

NOTE The fundamental resonance frequency of the accelerometer should not be confused with the resonance frequency of the accelerometer when mounted on a hand-held workpiece or power tool which is a characteristic of the whole accelerometer mounting system. In practice, the resonance of the mounted accelerometer on a hand-held workpiece or power tool will be substantially lower than the fundamental resonance frequency (see 6.1.4).

#### 6.1.2.4 Mass influence



When accelerometers are attached to a vibrating surface the vibration characteristics of that surface are altered. The lighter the accelerometer(s) the smaller the error introduced (see 6.1.5).

#### 6.1.2.5 Environmental conditions



When selecting accelerometers, particularly for use in harsh environments, it will be necessary to consider the accelerometer's sensitivity to temperature, humidity or other environmental factors (see ISO 8041).

### 6.1.3 Location of accelerometers

Vibration measurements in accordance with ISO 5349-1 should be made at or near the surface of the hand (or hands) where the vibration enters the body. Preferably, the accelerometer should be located at the middle of the gripping zone (e.g. halfway along the width of the hand when gripping a power tool handle), it is at this location that the most representative evaluation of the vibration entering the hand is obtained. However, it is generally not possible to locate transducers at this point; the transducers will interfere with the normal grip used by the operator.

Measurements directly under the hand are usually only possible using special mounting adaptors (see annex D). Such adaptors should fit under the hand, or between the fingers. For most practical measurements, the accelerometers are mounted either side of the hand or on the underside of the tool handle adjacent to the middle of the hand. With adaptors which fit between the fingers, the transducers should be mounted as close as possible to the surface of the tool handle to minimize amplification of rotational vibration components. They should not have any structural resonances which would affect the measured vibration.

It is possible to get differences in vibration measurement across the width of the hand, particularly for hand-held power tools with side handles, such as angle grinders, and especially where these handles are flexibly mounted. In these cases it is recommended that two accelerometers positions are used, located at the sides of the hand; the average of the two vibration measurements is then used to estimate vibration exposure.

For many hand-held power tools, specific measurement locations and axes have been defined for the measurement of vibration emission by ISO 8662 and other International Standards; these measurement locations are summarized in annex A as examples of measurement locations. The measurement locations defined in ISO 8662 are designed for a particular type of measurement (usually single axis only) and are not necessarily suitable for the evaluation of vibration exposure. However, in some circumstances it may be appropriate to ensure

 