# TECHNICAL SPECIFICATION

# ISO/TS 15694

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# Mechanical vibration and shock — Measurement and evaluation of single shocks transmitted from hand-held and hand-guided machines to the hand-arm system

*Vibrations et chocs mécaniques — Mesurage et évaluation des chocs simples transmis par les machines portatives et guidées à la main au système main bras*



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ISO/TS 15694 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 pre-Standard...” to mean “...this Technical Specification...”.

 

# Contents





 

# Foreword

This document (CEN ISO/TS 15694:2004) 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".

Annexes A, D and E are normative, Annexes B and C are informative.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to announce this CEN Technical Specification: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom

## Introduction

The effects of repeated shock-type excitations on the hand-arm system are not fully understood. A literature review ([5], [9] and [11]) shows that there is insufficient knowledge to establish whether the methods from EN ISO 5349-1 can be used for the assessment of health risks from shock-type loading of the hand and arm.

In spite of the lack of knowledge in this field, it is desirable to standardise methods for describing shock-type excitation from hand-held and hand-guided machinery. The purpose of this Technical Specification is to define methods

— for gathering consistent data on hand-transmitted single shocks under closely defined conditions and according to uniform criteria and

— for providing information on the shock emission of a given power tool, allowing an objective comparison of different power tools.

Power tools causing shock-type exposure are, for example, nailers, tackers, staplers and setting tools. Impact wrenches and nut runners are not included because it is not usually possible to trigger a single shock for these power tools.

Methods for the interpretation of the potential human effects of single shocks would be desirable but the lack of knowledge does not, at present, allow for the inclusion of such methods in a standard; in the future it is expected that these areas will be included.



The specification for instrumentation in ENV 28041 does not adequately describe the phase response, or the flat frequency response, for measurement of single shocks.

## 1 Scope

This Technical Specification specifies methods for measuring single shocks at the handle(s) of hand-held and hand-guided machinery characterised by a maximum strike rate below 5 Hz.

NOTE In order to describe the characteristics of single shocks, this Technical Specification defines quantities for the evaluation which go beyond those defined for hand-transmitted vibration in EN ISO 5349-1.

This Technical Specification also defines additional requirements for the measuring instrumentation which is necessary for the evaluation of shocks (see Annexes A, B, D and E).

The aim is to facilitate the gathering of emission and human exposure data in order to provide a basis for emission declaration and for the future development of exposure risk criteria. However, this Technical Specification does not provide methods for the interpretation of the potential human effects of single shocks.

This Technical Specification therefore is a basis for measurement and evaluation of emission of single shocks from hand-held and hand-guided machinery but does not cover the evaluation of human exposure.

## 2 Normative references

This Technical Specification 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 Technical Specification only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).



EN 1033, *Hand-arm vibration — Laboratory measurement of vibration at the grip surface of hand-guided machinery — General*

ENV 28041, *Human response to vibration — Measuring instrumentation (ISO 8041:1990)*

EN ISO 5349-1:2001, *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 1: General requirements (ISO 5349-1:2001)*

EN 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 5349-2:2001)*

CEN ISO/TS 8662-11, *Hand-held portable power tools — Measurement of vibrations at the handle — Part 11: Fastener driving tools (nailers) (ISO 8662-11:1999 + Amd. 1:2001)*

ISO 5348, *Mechanical vibration and shock — Mechanical mounting of accelerometers*

## 3 Terms and definitions

For the purposes of this Technical Specification, the symbols given in EN ISO 5349-1 and the terms and definitions given in EN ISO 5349-2 and the following apply.

**3.1**
**single shock**
short burst of acceleration

NOTE 1 The acceleration time history of a single shock includes a rise to a peak value (see 4.7), followed by a decay of the acceleration envelope.

NOTE 2 In principle a single shock could also be defined by other physical quantities, for example force or mechanical power transmitted to the hand-arm system. Due to practical measurement considerations, however, the restricted definition in terms of acceleration is used (see also Annex C).

EXAMPLE Power tools causing single shocks or single-shock vibration are nailers, tackers, staplers, setting tools, etc. These power tools produce a burst of high acceleration with short duration (e.g. 10 ms). The period between two shocks is much longer than the shock itself (e.g. greater than 200 ms).

**3.2**
**single-shock vibration**
series of single shocks separated by periods of zero acceleration

EXAMPLE See example in 3.1.

**3.3**
**repetition time**
$T_{rep}$
time interval between two consecutive single shocks

**3.4**
**strike rate**
$f_0$
for constant repetition time $T_{rep}$, the reciprocal of the repetition time, i.e. $f_0 = 1/T_{rep}$

**3.5**
**flat$_h$**
designation for unweighted acceleration which is band-limited as specified in 4.2 and Annex D

## 4 Parameters for describing single shocks



### 4.1 Acceleration

The basic quantity for describing single shocks is the acceleration $a(t)$. It is the basis of all parameters used in this Technical Specification.



NOTE For use of the vibration velocity to describe single shocks, see Annex C.

### 4.2 Flat$_h$-weighted acceleration

The flat$_h$-weighted acceleration $a_{hF}(t)$ is the band-limited acceleration in the frequency band from 6,3 Hz to 1250 Hz. The filter for the flat$_h$ weighting is specified in Annex D.

NOTE 1 This frequency band corresponds to the octave bands from 8 Hz to 1000 Hz. In some cases a wider pass band is required; variations should then be reported with the measurement values.

NOTE 2 The flat$_h$ weighting differs from the flat responses often provided on measuring instrumentation by a clearly defined frequency band and phase response.

NOTE 3 Unweighted acceleration in this Technical Specification means band-limited acceleration in the frequency band with a low-pass corner frequency greater than 1250 Hz.

### 4.3 Root-mean-square value of flat$_h$-weighted acceleration

Using the specification in 4.2 the root-mean-square (r.m.s.) value of $a_{hF}(t)$ in a time interval $T$ is given by

$$a_{hF,RMS,T} = \sqrt{\frac{1}{T}\int_0^T a_{hF}^2(t)\,\mathrm{d}t} \tag{1}$$

It describes the energy-equivalent average value of the signal. A prescribed fixed integration time of $T = 3$ s allows comparison of various measurement results and helps the tool operator to achieve reproducibility.

 

Experience shows that $T = 3\,\text{s}$ is a good compromise between the reaction time of the operator and the requirement for shortest practicable integration time. In order to increase the confidence level of the results it is advisable to take the average of this quantity over a series of single shocks (see 6.3).

### 4.4 Running root-mean-square value of flat$_h$-weighted acceleration

Using the specification in 4.2 the running root-mean-square value of $a_{hF}(t)$ at time of observation, $t$, is given by

$$a_{hF,RRMS,\tau}(t) = \sqrt{\frac{1}{\tau}\int_0^t a_{hF}^2(\xi)\,\mathrm{e}^{-\frac{t-\xi}{\tau}}\,\mathrm{d}\xi} \qquad (2)$$

where

$t$ is the time of observation (actual time)

$\xi$ is the integration variable

$\tau$ is a time constant which is to be specified. A time constant $\tau$ = 0,125 s is preferred.

In order to increase the confidence level of the results it is advisable to take the average of this quantity over a series of single shocks (see 6.3).



NOTE 1 The exponential averaging function describes the behaviour of many natural processes. It can be generated by very simple analogue or digital signal processing. The true running r.m.s. acceleration value, obtained by linear integration over a running time interval of fixed length, looks simpler mathematically but would, in reality, be more difficult to achieve with analogue instrumentation without any advantage.



NOTE 2 Other International Standards prefer the linear averaging for the running root-mean-square value, which is defined as follows:

$$a_{hF,RRMS,\tau}(t) = \sqrt{\frac{1}{\tau}\int_0^t a_{hF}^2(\xi)\,\mathrm{d}\xi}$$

### 4.5 Root-mean-quad value of flat$_h$-weighted acceleration

Using the specification in 4.2 the root-mean-quad (r.m.q.) value of $a_{hF}(t)$ in a time interval $T$ is given by

$$a_{hF,RMQ,T} = \sqrt[4]{\frac{1}{T}\int_0^T a_{hF}^4(t)\,\mathrm{d}t} \qquad (3)$$

As with the root-mean-square value in 4.3 it describes an average value of the signal. However, with the r.m.q. average the influence of the higher magnitudes is stronger than with the r.m.s. A prescribed fixed integration time of $T = 3\,\text{s}$ allows comparison of various measurement results and helps the tool operator to achieve reproducibility. Experience shows that $T = 3\,\text{s}$ is a good compromise between the reaction time of the operator and the requirement for shortest practicable integration time. In order to increase the confidence level of the results it is advisable to take the average of this quantity over a series of single shocks (see 6.3).

### 4.6 Maximum transient vibration value of flat$_h$-weighted acceleration

Using the specifications in 4.4 the maximum transient vibration value (MTVV) in the time interval $T$ is the highest magnitude of $a_{hF,RRMS,\tau}(t)$ as given by

$$a_{hF,MTVV,\tau} = \max_{0 \le t \le T} \left\{ a_{hF,RRMS,\tau}(t) \right\} \quad (4)$$

In order to increase the confidence level of the results it is advisable to take the 50th percentile of this quantity over a series of single shocks.

### 4.7 Peak value of flat$_h$-weighted acceleration

For any specified time interval $0 \le t \le T$, the peak value (PV) of $a_{hF}(t)$ is the maximum absolute instantaneous value, as given by

$$a_{hF,PV} = \max_{0 \le t \le T} \left\{ \left| a_{hF}(t) \right| \right\} \quad (5)$$

This quantity is used to describe the top level of the signal. In order to increase the confidence level of the results it is advisable to take the 50th percentile of this quantity over a series of single shocks.

### 4.8 Crest factor of flat$_h$-weighted acceleration

Using the quantities in 4.3 and 4.7 the crest factor of the flat$_h$-weighted acceleration, $CF_h$, is obtained by dividing the peak value of flat$_h$-weighted acceleration by the root-mean-square value of the flat$_h$-weighted acceleration measured in the same time period $T$:

$$CF_h = \frac{a_{hF,PV}}{a_{hF,RMS,T}} \quad (6)$$



This quantity combines the peak value of the signal with the energy-equivalent r.m.s. value and therefore describes the impulsiveness of the flat$_h$-weighted signal.



### 4.9 Shock content quotient of flat$_h$-weighted acceleration

Using the quantities in 4.3 and 4.5 the shock content quotient of the flat$_h$-weighted acceleration, $SC_h$, is obtained by dividing the root-mean-quad value of the flat$_h$-weighted acceleration by the root-mean-square value of the flat$_h$-weighted acceleration measured in the same time period $T$:

$$SC_h = \frac{a_{hF,RMQ,T}}{a_{hF,RMS,T}} \quad (7)$$

This quantity also describes the impulsiveness of the signal.

### 4.10 W$_h$-weighted acceleration

The frequency weighting characteristic W$_h$, used for the measurement and evaluation of hand-transmitted vibration, is defined in EN ISO 5349-1 and is precisely specified in Annex E. W$_h$-weighted acceleration is denoted by $a_{hw}(t)$.

NOTE 1 $a_{hw}(t)$ may be derived from $a_{hF}(t)$ (see 4.2) by applying an acceleration-velocity transition function (a-v-transition) which converts acceleration into velocity for frequencies above 16 Hz.

NOTE 2 Although the frequency weighting in EN ISO 5349-1 was originally defined in order to assess periodic and random or non-periodic vibration, EN ISO 5349-1:2001 states that it may provisionally "also be applied to repeated shock type excitation (impact)." In addition, use of the W$_h$ frequency weighting allows comparison with existing data. Furthermore, measurements of parameters based on $a_{hw}(t)$ can be more reproducible, because problematic higher-frequency components are attenuated.

The order of presentation chosen in this Technical Specification (flat$_h$ weighting, followed by W$_h$ weighting) does not imply that the former is preferred.

 

### 4.11 Root-mean-square value of $W_h$-weighted acceleration

Using the specification in 4.10 the root-mean-square value of $a_{hw}(t)$ in a time interval $T$ is given by

$$a_{hw,RMS,T} = \sqrt{\frac{1}{T}\int_0^T a_{hw}^2(t)\,\mathrm{d}t} \quad (8)$$

It describes the energy-equivalent average value of the signal. A prescribed fixed integration time of $T = 3\,\mathrm{s}$ allows comparison of various measurement results and helps the tool operator to achieve reproducibility. Experience shows that $T = 3\,\mathrm{s}$ is a good compromise between the reaction time of the operator and the requirement for shortest practicable integration time. In order to increase the confidence level of the results it is advisable to take the average of this quantity over a series of single shocks (see 6.3).

### 4.12 Root-mean-quad value of $W_h$-weighted acceleration

Using the specification in 4.10 the root-mean-quad value of $a_{hw}(t)$ in a time interval $T$ is given by

$$a_{hw,RMQ,T} = \sqrt[4]{\frac{1}{T}\int_0^T a_{hw}^4(t)\,\mathrm{d}t} \quad (9)$$



As with the root-mean-square value in 4.11 it describes an average value of the signal. However, with the r.m.q. average the influence of the higher magnitudes is stronger than with the r.m.s. A prescribed fixed integration time of $T = 3\,\mathrm{s}$ allows comparison of various measurement results and helps the tool operator to achieve reproducibility. Experience shows that $T = 3\,\mathrm{s}$ is a good compromise between the reaction time of the operator and the requirement for shortest practicable integration time. In order to increase the confidence level of the results it is advisable to take the average of this quantity over a series of single shocks (see 6.3).



### 4.13 Shock content quotient of $W_h$-weighted acceleration

Using the specifications in 4.11 and 4.12 the shock content quotient of $a_{hw}(t)$ is given by the quotient of the root-mean-quad and the root-mean-square values measured in the same time period *T*:

$$SC_{hw} = \frac{a_{hw,RMQ,T}}{a_{hw,RMS,T}} \quad (10)$$

This quantity describes the impulsiveness of the $W_h$ frequency-weighted signal.

## 5 Measuring instrumentation

The root-mean-square value of the $\text{flat}_h$-weighted acceleration and $W_h$-weighted acceleration, defined in 4.3 and 4.11, with integration time $T = 3\,\mathrm{s}$, can be determined with measuring instrumentation in accordance with ENV 28041 as long as the frequency band of the flat response of the instrumentation is as defined in 4.2. For the evaluation of all other parameters, the acceleration has to be measured with instrumentation which conforms to the requirements of Annex A (for digital measuring instrumentation, see also Annex B).

NOTE The requirements of Annex A exceed those specified in ENV 28041.

In practice, it will be difficult to satisfy the requirements of all the annexes if mechanical filters are used.