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Mechanical vibration — Laboratory method for evaluating vehicle seat vibration —

Part 2:
Application to railway vehicles

Vibrations mécaniques — Méthode en laboratoire pour l'évaluation des vibrations du siège de véhicules —

Partie 2: Application aux véhicules ferroviaires

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 4, *Human exposure to mechanical vibration and shock.*

This second edition cancels and replaces the first edition (ISO 10326-2:2001), which has been technically revised.

The main changes are as follows:

- propositions of new excitation signals to measure seat transmissibility: a lower level of narrowband vibration, and measured or reproduced real train stimuli to better consider the non-linearity of the human-seat system;
- propositions to calculate the SEAT “predicted” value from the measured seat transmissibility and real train stimuli.

Annex B gives an example to build an excitation signal for seat testing from a trains’ vibration characteristics.

A list of all parts in the ISO 10326 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Although the vibration felt by passengers in railway vehicles is always of low magnitude, the fact nevertheless remains that acceleration at the seat-buttock and seat-backrest interfaces can sometimes be greater than excitations transmitted by the vehicle frame. Consequently, the aim of laboratory tests to be carried out with railway seats is fundamentally to refine existing knowledge about their overall dynamic behaviour and that of their different components: seat frame, suspension system, linings, coverings, etc. In the long run, the knowledge should provide useful guidance in choosing the optimum components, and for improving passenger comfort further in the process.

Laboratory tests can be performed under clearly defined and reproducible excitation conditions, to complement studies carried out in the field. They consequently represent an essential study method complementary to the investigations performed in the field.

The vibration at the base of railway seats is of the random, broad-band type. The spectra, which are of complex form and non-stationary, depend on the vehicle itself, on its load, on wheel profile conditions, on track geometry and quality, etc. In this document, therefore, it is stipulated to excite the seat, occupied by a test person, by means of various types of excitation (such as pseudo-random; sinusoidal; and realistic, as discussed in Clause 11):

- A broad-band pseudo-random vibration successively in the three directions *X, Y* and *Z*. The vibration spectra are of sufficiently simple form and of sufficient magnitude to cover the majority of actual spectra observed on track, whilst nevertheless remaining quite different from the latter.
- Similar broad-band pseudo-random vibration in the three direction *X, Y* and *Z* simultaneously. It considers the cross-axis responses (response in a direction caused by an excitation in another direction), which represents a more realistic test condition. Also, it shortens the test duration.
- Investigations carried out under the effect of sinusoidal vibration can allow detection of possible non-linearities.
- If the seat vibration exposure is known, specific spectra and phase (either simulated or measured) can be used in the laboratory. This specific excitation can be successively used in the three directions *X, Y* and *Z* on the platform, or used simultaneously if the simulator has the abilities. The advantage of such stimuli is the representability of the actual response of the seat in its environment. As the seat and human are non-linear systems, having the right input excitation provides confidence in the measured output vibration of the seat interfaces.

Calculations, using broad-band pseudo random excitations, are, however, truly valid only on the assumption that the human-seat system considered is sufficiently linear. To check this assumption under laboratory conditions, this document stipulates an extra testing phase during which the seat is excited in a purely sinusoidal, high-amplitude mode at the different frequencies encountered during tests under random excitations, and corresponding to the peaks of the frequency response function. If the system shows non-linearity it is advised to used input spectra and phase representative of the vibration exciting the seat.

As a result, the magnitudes measured at the different response points of the human-seat system during laboratory tests, using broad-band pseudo random excitations, could under no circumstances be used for comparison with limits or acceptable values. By contrast, it is stipulated using the measurements to determine the frequency response function of the human-seat system at seat pan and backrest level in the three directions *X, Y* and *Z*. These frequency response functions suffice for characterizing the vibratory behaviour of the seat with its occupant. The directions of excitation, favourable or harmful frequencies, and corresponding gains are thus clearly demonstrated. These inputs are relevant to a comparison of seats with different construction arrangements.

The frequency range relevant to railway conditions is limited to 0,5 Hz to 50 Hz. Railway seats transmit vibration with frequencies lower than 0,5 Hz without amplification. However, vibration with frequencies of over 50 Hz, as sustained by seats in service, is generally of too small a magnitude to be felt by seated passengers. For suspension seats, ISO 10326-1 is recommended.

The discomfort for passengers of railway vehicles can be assessed using ISO 2631-4 or EN 12299.

Mechanical vibration — Laboratory method for evaluating vehicle seat vibration —

Part 2:
Application to railway vehicles

1 Scope

This document defines specifications covering laboratory tests for seats designed for passengers and crew in railway tractive and trailer vehicles.

It concerns tri-axial rectilinear vibration within the frequency range 0,5 Hz to 50 Hz. It specifies the input test vibration to be used at seat testing.

This document makes it possible to characterize, in the form of frequency response functions, the manner in which vibration is transmitted to the seat occupant. It also provides an estimator showing the behaviour of the seat in terms of dynamic comfort perceived by the seated person.

Different types of excitations can be used and are described depending on knowledge of the vibration environment encountered by the seat and the capability of the vibration simulator.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 5347 (all parts), *Methods for the calibration of vibration and shock pick-ups*

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

ISO 8041-1, *Human response to vibration — Measuring instrumentation — Part 1: General purpose vibration meters*

ISO 10326-1:2016, *Mechanical vibration — Laboratory method for evaluating vehicle seat vibration — Part 1: Basic requirements*

ISO 13090-1, *Mechanical vibration and shock — Guidance on safety aspects of tests and experiments with people — Part 1: Exposure to whole-body mechanical vibration and repeated shock*

ISO 16063 (all parts), *Methods for the calibration of vibration and shock transducers*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.2 Symbols and abbreviated terms

The following symbols and abbreviated terms are used in this document:

a_{rms}	root-mean-square (rms) value of acceleration, m/s^2
a_{W}	weighted root-mean-square value of acceleration (using frequency weighting described in ISO 2631-1), m/s^2
$W(f)$	appropriate frequency weighting for vibration discomfort (as described in ISO 2631-1)
$a(t)$	instantaneous value of an acceleration time history, m/s^2
$a(t,B_{\mathrm{e}},f)$	instantaneous value of the acceleration time history $a(t)$, filtered in the frequency range $(f - B_{\mathrm{e}}/2)$ to $(f + B_{\mathrm{e}}/2)$, m/s^2
$b(t)$	instantaneous value of an acceleration time history, m/s^2
$b(t,B_{\mathrm{e}},f)$	instantaneous value of the acceleration time history $b(t)$, filtered in the frequency range $(f - B_{\mathrm{e}}/2)$ to $(f + B_{\mathrm{e}}/2)$, m/s^2
$b'(t,B_{\mathrm{e}},f)$	instantaneous value of the acceleration time history $b(t)$, filtered in the frequency range $(f - B_{\mathrm{e}}/2)$ to $(f + B_{\mathrm{e}}/2)$, with phase shifted by $\pi/2$, m/s^2
B	acceleration measuring point on the backrest of a seat occupied by a subject
B_{e}	resolution bandwidth of a frequency analysis, Hz
$C_{\mathrm{ab}}(f)$	real part of $G_{\mathrm{ab}}(f)$, (m/s^2)^2/Hz
d	displacement amplitude at a single frequency, m
f	frequency, Hz
f_{r}	frequency corresponding to a peak of the frequency response function, Hz
$G_{\mathrm{aa}}(f)$	acceleration power auto spectral density function of the time history $a(t)$, being the mean-square value of acceleration per unit frequency bandwidth, (m/s^2)^2/Hz
$G_{\mathrm{ab}}(f)$	cross power spectral density function of two acceleration time histories, $a(t)$ and $b(t)$, being a complex function, also called acceleration cross spectral density, (m/s^2)^2/Hz
$\lvert G_{\mathrm{ab}}(f)\rvert$	modulus of $G_{\mathrm{ab}}(f)$, (m/s^2)^2/Hz
$G_{\mathrm{bb}}(f)$	acceleration power auto spectral density function of the time history b(t), being the mean-square value of acceleration per unit frequency bandwidth, (m/s^2)^2/Hz
$H(f)$	frequency response function, being a dimensionless complex function of frequency
P	acceleration measuring point on the test platform
PSD	power spectral density
$Q_{\mathrm{ab}}(f)$	imaginary part of $G_{\mathrm{ab}}(f)$, (m/s^2)^2/Hz
S	acceleration measuring point on the seat pan of the seat occupied by a subject
t	time, s

T	duration of signal measurement and analysis, s
T_R	transmissibility (dimensionless)
x, y and z	letters used in characterizing the direction of vibration at seat pan and backrest, points S and B
X, Y and Z	letters used in characterizing the direction of platform vibration at point P
$\gamma_{ab}^2(f)$	coherence function between the two accelerations $a(t)$ and $b(t)$, being a dimensionless function in the range 0 to 1
$\Theta_{ab}(f)$	phase of $G_{ab}(f)$, being a real function, rad

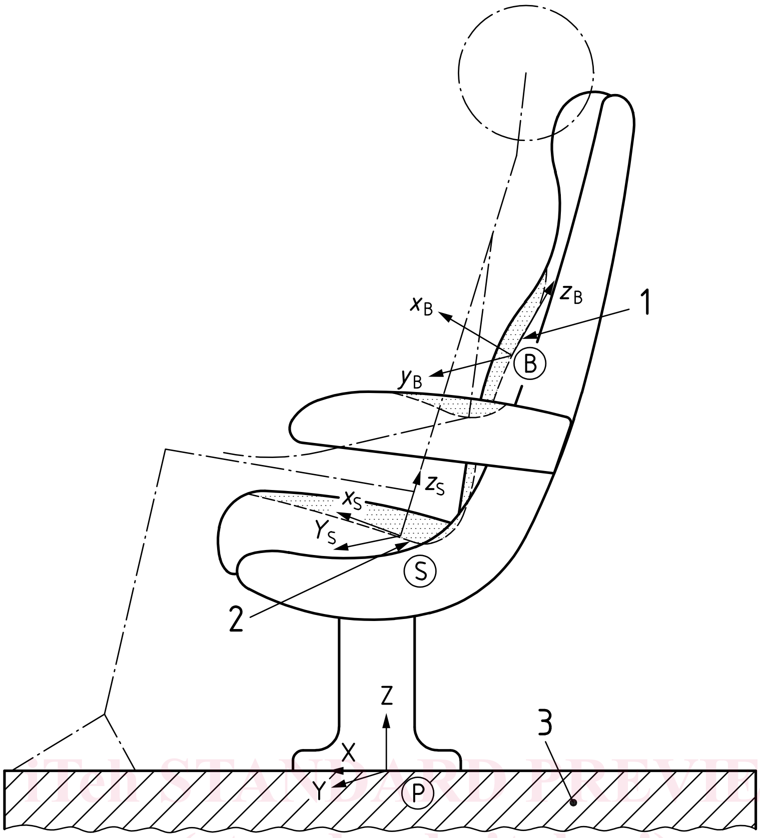
The following subscripts are used in this document:

i	direction of platform vibration, taking the values X, Y or Z
k	direction of vibration at points S or B, taking the values x, y or z
rms	root-mean-square value
s	subscript denoting that the results of three consecutive tests have been averaged
w	subscript characterizing a parameter calculated on the basis of frequency-weighted signals
α	subscript characterizing the location of an acceleration measuring point: S (seat pan) and B (backrest)

4 Direction of vibration

The coordinate axes X, Y and Z for the evaluation of human exposure to whole-body vibration in accordance with this document are defined in ISO 2631-1 by the orthogonal biodynamic coordinate system shown in Figure 1. For the purposes of this document, two such basicentric coordinate systems are used, with their origins at the interface at the buttocks and the seat cushion, and at the interface of the back of a seated person and the backrest of the seat. Their axes are approximately parallel to the axes shown in Figure 1.

The coordinate axes for describing rectilinear vibration of the vehicle are defined by an orthogonal coordinate system parallel to the principal axes of the vehicle. The X-axis is parallel to the longitudinal axis, the Y-axis parallel to the transverse axis and the Z-axis upwards perpendicular to the plane defined by the X and Y axes. The coordinate system for the description of the vehicle vibration is usually not parallel to the coordinate systems for the seat occupant because of practical reasons such as seat cushion angles or actual position of the seat with respect to the longitudinal axis of the vehicle.



Key

1	seat backrest	B	output accelerations on the backrest
2	seat pan	S	output accelerations on the seat pan
3	platform	P	input accelerations from the vibrating platform

NOTE The arrows indicate the positive directions.

Figure 1 — Directions of vibration measurements

5 Characterization of vibration and of its transmission

5.1 Characterization of vibration

5.1.1 General

Three quantities shall be used to describe the vibration, root-mean-square acceleration, acceleration power spectral density and acceleration cross spectral density.

5.1.2 Root-mean-square acceleration, a_{rms}

The root-mean-square value of the acceleration signal, a_{rms}, shall be calculated by a method equivalent to that described by the following Formula (1):

$$a_{\mathrm{rms}} = \left[\frac{1}{T} \int_0^T a^2(t)\,\mathrm{d}t \right]^{1/2} \tag{1}$$