INTERNATIONAL STANDARD

ISO 10326-2

First edition
2001-08-15

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

Reference number
ISO 10326-2:2001(E)

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

Printed in Switzerland

Contents

Page

Foreword ... iv
Introduction ... v
1 Scope ... 1
2 Normative references ... 1
3 Terms, definitions, symbols and abbreviated terms ... 2
3.1 Terms and definitions ... 2
3.2 Symbols and abbreviated terms ... 2
4 Direction of vibration ... 3
5 Characterization of vibration and of its transmission ... 3
5.1 Characterization of vibration ... 3
5.2 Characterization of vibration transmission ... 5
6 General observations ... 6
7 Measurement positions ... 6
8 Instrumentation ... 6
9 Safety requirements ... 8
10 Test seats and test persons ... 8
10.1 Test seats ... 8
10.2 Test persons ... 8
11 Input test vibration ... 9
11.1 General ... 9
11.2 Pseudo-random excitation ... 9
11.3 Sinusoidal excitation ... 9
12 Parameters adopted for characterizing the vibration transmission ... 10
12.1 Pseudo-random excitation ... 10
12.2 Sinusoidal excitation ... 10
13 Test procedure ... 10
13.1 Initial procedure ... 10
13.2 Tests under pseudo-random excitation ... 10
13.3 Tests under sinusoidal excitation ... 11
14 Test report ... 11
14.1 Seat ... 11
14.2 Test persons ... 11
14.3 Measuring chain ... 11
14.4 Results ... 11
Annex A (informative) Example of excitation generating process ... 14
Bibliography ... 17

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 10326 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10326-2 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

ISO 10326 consists of the following parts, under the general title *Mechanical vibration — Laboratory method for evaluating vehicle seat vibration*:

— *Part 1*: *Basic requirements*

— *Part 2: Application to railway vehicles*

Annex A of this part of ISO 10326 is for information only.

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 experiments to be carried out with railway seats must fundamentally be 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 put together 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. 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 part of ISO 10326, therefore, it is stipulated to excite the seat, occupied by a test person, by means of 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.

As a result, the magnitudes measured at the different response points of the man-seat system during laboratory tests 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 man-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.

Frequency response functions may be used to evaluate, by the automatic calculation method, the qualitative behaviour of a given seat subjected to excitation similar to that it would encounter in service on a real vehicle. To this end, they must be ascertained not only in modulus but also in phase terms. Direct and cross ratios are just as relevant, as couplings can exist between vertical, lateral and longitudinal movements. The test code described in this part of ISO 10326 allows for these interactions.

Such calculations are, however, truly valid only on the assumption that the man-seat system considered is sufficiently linear. To check this assumption under laboratory conditions, this part of ISO 10326 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.

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 modifying them. 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.

Mechanical vibration — Laboratory method for evaluating vehicle seat vibration —

Part 2:
Application to railway vehicles

1 Scope

This part of ISO 10326 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 part of ISO 10326 makes it possible to characterize, in the form of frequency response functions, the manner in which vibration is transmitted to the seat occupant. However, this characterization is fully valid only when the man-seat system can be considered to be sufficiently linear.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 10326. 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 10326 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 2631-1, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*.

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, *Human response to vibration — Measuring instrumentation*.

ISO 10326-1:1992, *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 part of ISO 10326, the terms and definitions given in ISO 2041 apply.

3.2 Symbols and abbreviated terms

The following symbols and abbreviated terms are used in this part of ISO 10326:

a_{rms} root-mean-square value of acceleration, m/s^2

$a(t)$ 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

$G_{\mathrm{a}}(f)$ acceleration power 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

$|G_{\mathrm{ab}}(f)|$ modulus of $G_{\mathrm{ab}}(f)$, (m/s^2)^2/Hz

$G_{\mathrm{b}}(f)$ acceleration power 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

$\gamma^2_{ab}(f)$ 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 part of ISO 10326:

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 part of ISO 10326 are defined in ISO 2631-1 by the orthogonal biodynamic coordinate system shown in Figure 1. For the purposes of this part of ISO 10326, 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.

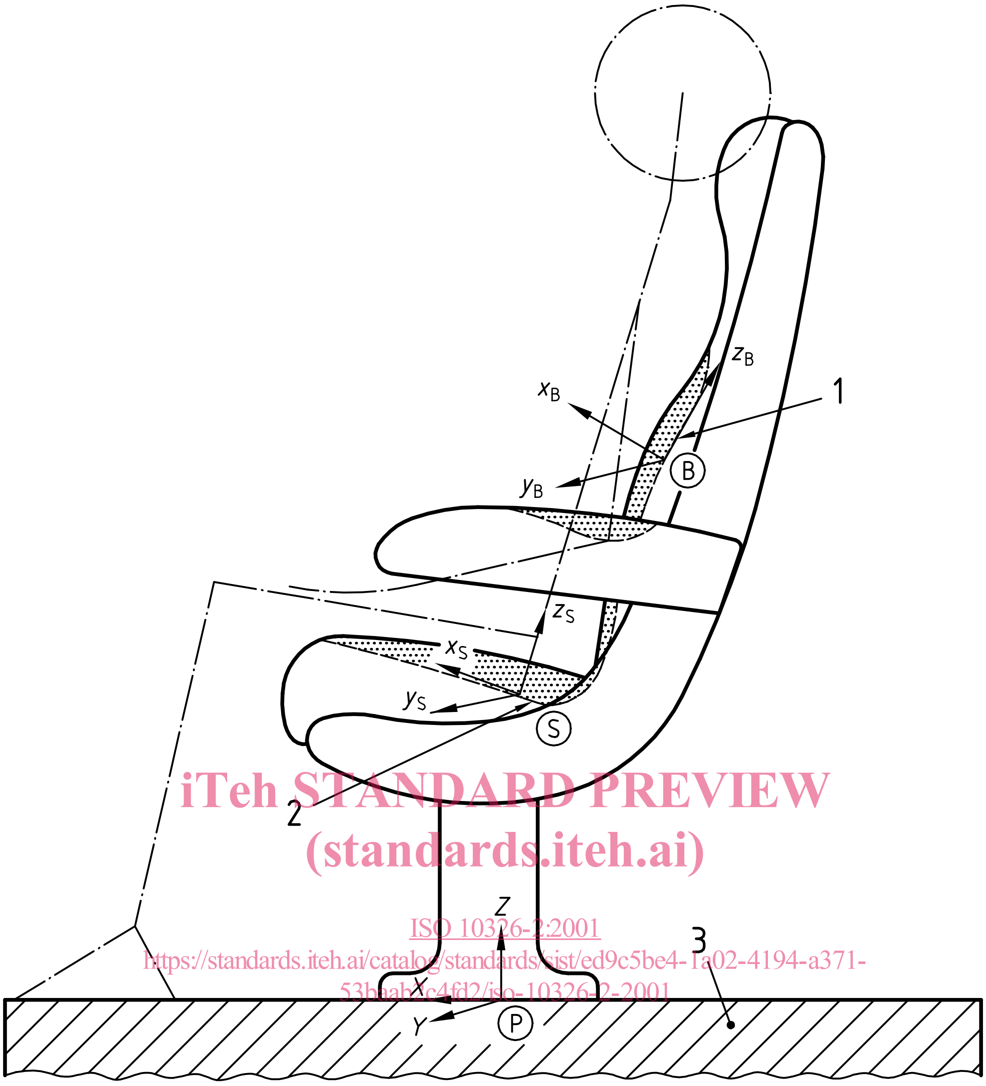
The coordinate axes for describing rectilinear vibration of the vehicle are defined by an orthogonal coordinate system parallel to the principal axes of the vehicle. The X-axis is parallel to the longitudinal axis, the Y-axis parallel to the transverse axis and the Z-axis upwards perpendicular to the 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.

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.



Key

1 Mounting disc

2 Seat pan

3 Platform

NOTE The arrows indicate the positive directions.

Figure 1 — Directions of vibration measurements

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 equation:

$$a_{rms} = \left(\frac{1}{T} \int_0^T a^2(t)\, dt \right)^{1/2} \qquad (1)$$

5.1.3 Acceleration power spectral density, $G_a(f)$

The acceleration power spectral density, $G_a(f)$, shall be estimated by a method equivalent to that described by the following equation:

$$G_a(f) = \frac{1}{B_e \cdot T} \int_0^T a^2(t, B_e, f)\,dt \tag{2}$$

5.1.4 Acceleration cross spectral density, $G_{ab}(f)$

This parameter is used for connecting two acceleration signals, one $a(t)$ or input acceleration for seat excitation, the other $b(t)$ or output acceleration response of man-seat system at a given interface point. The cross power spectral density, $G_{ab}(f)$, shall be estimated by a method equivalent to that described by the following equation:

$$G_{ab}(f) = C_{ab}(f) - j\,Q_{ab}(f) = \left| G_{ab}(f) \right| e^{-j\Theta_{ab}(f)} \tag{3}$$

where

$$C_{ab}(f) = \frac{1}{B_e \cdot T} \int_0^T a(t, B_e, f) \cdot b(t, B_e, f)\,dt$$

$$Q_{ab}(f) = \frac{1}{B_e \cdot T} \int_0^T a(t, B_e, f) \cdot b'(t, B_e, f)\,dt$$

$$\left| G_{ab}(f) \right| = \sqrt{C_{ab}^2(f) + Q_{ab}^2(f)}$$

$$\Theta_{ab}(f) = \arctan \frac{Q_{ab}(f)}{C_{ab}(f)}$$

5.2 Characterization of vibration transmission

5.2.1 General

The following parameters shall be used to characterize the transmission of vibrations from their input at the seat fastening point, acceleration signal $a(t)$, up to their output at a man-seat interface point, acceleration signal $b(t)$.

5.2.2 Frequency response function, $H(f)$

This is a dimensionless complex function of frequency f. It shall be calculated by means of a method equivalent to that described by the following equation:

$$H(f) = G_{ab}(f) / G_a(f) \tag{4}$$

5.2.3 Coherence function, $\gamma_{ab}^2(f)$

This is a dimensionless real function of frequency f. It shall be calculated by means of a method equivalent to that described by the following equation:

$$\gamma_{ab}^2(f) = \frac{\left| G_{ab}(f) \right|^2}{G_a(f) \cdot G_b(f)} \tag{5}$$

