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Mechanical vibration — Measurement and analysis of whole-body vibration to which passengers and crew are exposed in railway vehicles

Vibrations mécaniques — Mesurage et analyse des vibrations globales du corps auxquelles sont exposés les passagers et le personnel de bord dans les véhicules ferroviaires

Reference number
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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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 10056 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*.

Annex A of this International Standard is for information only.

Introduction

This International Standard specifies a method which can be applied to the railway environment for the measurement and analysis of vibration, bearing in mind that mechanical vibration in a railway vehicle has specific characteristics.

It supplements ISO 2631-1 which deals in a general way with all the situations encountered by man in his day-to-day activities (work, travel, etc.), and describes measurement of whole-body vibration and its effects.

Mechanical vibration — Measurement and analysis of whole-body vibration to which passengers and crew are exposed in railway vehicles

1 Scope

This International Standard defines a method for measuring and analysing the mechanical vibration of railway vehicles during field tests. It deals with periodic, random and transient vibration over the range of frequencies from 0,5 Hz to 80 Hz which are transmitted to the whole human body. This International Standard covers standing and seating positions only.

This International Standard is not applicable to vibration transmitted to the hand-arm system, nor to very-low-frequency lateral, vertical or rotational motion which may be associated with kinetosis (motion sickness). This International Standard does not propose methods for assessing the effects of vibration. This is covered by ISO 2631-1 and, for fixed guideway transport systems, by ISO 2631-4.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard 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 2631-4, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 4: Guidelines for the evaluation of the effects of vibration and rotational motion on passenger and crew comfort in fixed-guideway transport systems*.

ISO 8002, *Mechanical vibrations — Land vehicles — Method for reporting measured data*.

ISO 10326-2, *Mechanical vibration — Laboratory method for evaluating vehicle seat vibration — Part 2: Application to railway vehicles*.

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

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

3.2 Symbols and abbreviated terms

In this International Standard, the following symbols and abbreviated terms are used:

a	root-mean-square value of acceleration, m/s^2
$a(t)$	instantaneous value of an acceleration time history, m/s^2
b	class width, m/s^2
B	acceleration measuring point on the backrest of a seat occupied by a subject
f	frequency, Hz
FFT	fast Fourier transform
h	probability histogram of the root-mean-square values of acceleration
h_c	cumulative probability histogram of the root-mean-square values of acceleration
m	index characterizing the class of an observation
$n(m)$	number of observations in class m
n_T	total number of observations
N	number of samples per elementary block
N_b	number of elementary blocks
P	acceleration measuring point on the floor (platform)
$p[...]$	probability that the condition in brackets is met
PSD	power spectral density
S	acceleration measuring point on the seat pan of the seat occupied by a subject
t	time, s
Δt	sampling interval, s
X	Fourier transform of acceleration, m/s^2
τ	duration of an elementary block, s

The following subscripts are used in this International Standard:

j	index characterizing the direction of vibration measured at point α and taking the values x, y, z (see Figure 1)
k	index characterizing the number of an elementary block of data
w	index characterizing a parameter calculated on the basis of weighted signals
α	index characterizing the location of the point for the measurement of acceleration: P (platform, floor), S (seat pan) and B (backrest)

4 Characterization of vibration in railway vehicles

4.1 Principal causes of vibration or amplification of vibration

4.1.1 Track

Although railway tracks ensure high-quality guidance, the track still has irregularities which cause vibration, such as the following:

— variation in track level (z-direction), alignment (y-direction) or gauge;

— welding or manufacturing defects of the rails;

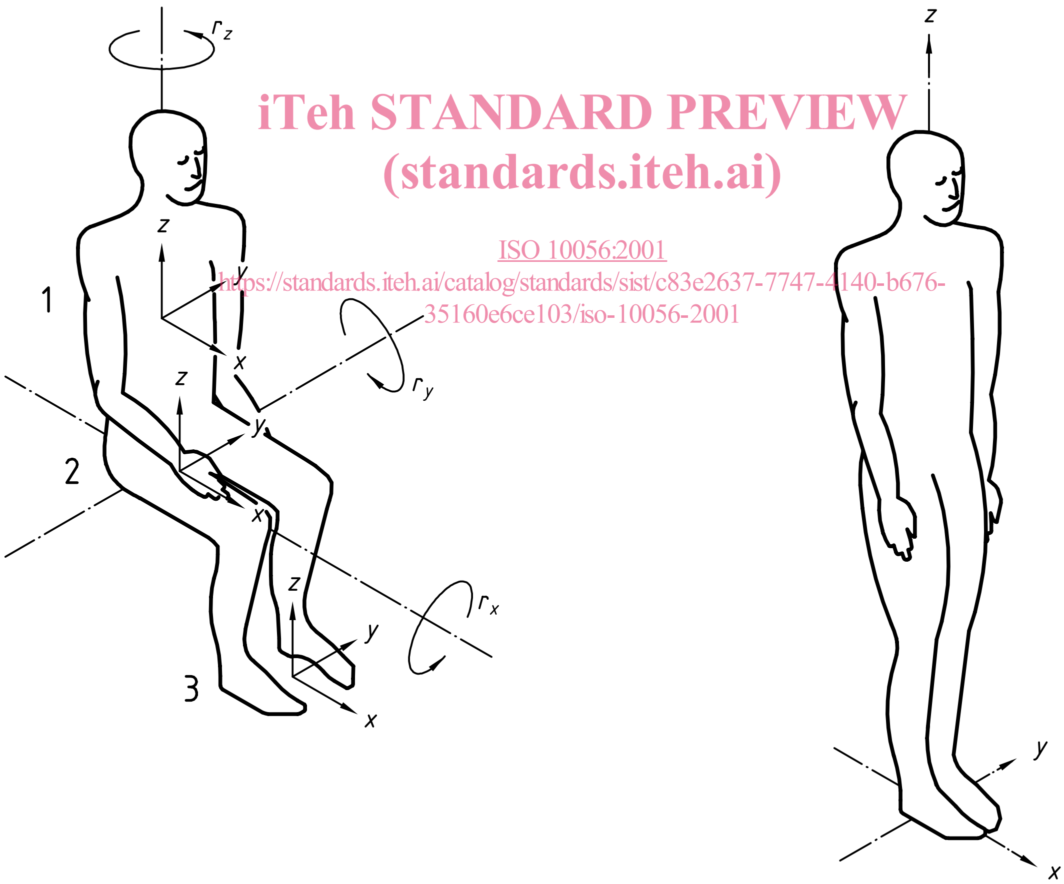
— rail joints;

— turnout;

— variable vertical stiffness of the track (e.g. bridges);

— level crossings;

— transition curves and super-elevation ramps, which can cause low-frequency vibration.



Key

1 Seat back

2 Seat surface

3 Feet

a) Principal basicentric axes for seating position **b) Basicentric axes for standing position**

Figure 1 — Basicentric axes of the human body

4.1.2 Contact between wheel and rail

Excitation of a rail vehicle is particularly localized at the wheel-to-rail contact. The rail-wheel contact forces are non-linear functions of displacement and velocity and produce vibration in the railway vehicle.

4.1.3 Vehicle

The body of a railway vehicle is a flexible complex structure whose natural vibration can at times be important. Moreover, its behaviour is influenced by its load, by the relative position of the bogies, by the various suspension parts (such as springs, dampers, etc.) and by adjacent vehicles in a train.

Defects in the running surfaces of the wheels (such as flats), and out-of-balance or eccentric wheelsets are sources of periodic vibration, the amplitude and frequency of which are a function of the speed.

Rotating machinery (such as motor compressor sets, diesel engines and air-conditioning equipment) can also create vibration which often also is periodic. Furthermore, acceleration and deceleration (e.g. braking) can excite both periodic and non-periodic vibration.

The non-linear behaviour of certain components (e.g. special dampers, buffers, transverse stops, etc.) can produce transient vibration.

The seat can amplify the vibration and can sometimes add some non-linearities, especially at its resonant frequencies. The response of the seat depends among other things on the way it is fixed, the mass and posture of the occupant of the seat, and the shape and material of the seat itself.

4.2 Nature of vibration

Railway vibration signals

— are of a random nature, can include periodic features and can cover a wide range of frequencies, but their energy level inside the vehicle is relatively low,

— have certain well-defined resonances (e.g. in the vertical direction the vehicle body has a natural frequency on the secondary suspension of about 1 Hz and a natural frequency of bending generally between 8 Hz and 15 Hz),

— are not stationary but may be considered as partially stationary, and

— can be permanent (e.g. vibration caused by track irregularities), temporary (e.g. vibration caused by air-conditioning units) or occasional (e.g. vibration caused by level crossings or turnout).

4.3 Direction of vibration

Generally speaking, at any point of the vehicle, the vibration accelerations are characterized by six components: three translational components and three rotational components along and around the x-, y- and z-axes, respectively. However, it is assumed that for rotational vibration the distance to the centre of rotation is large enough to consider this vibration as translational.

For more details of measurement of rotational vibration, see ISO 2631-4.

5 Method of measurement

5.1 General

The physical parameters to be measured are the translational accelerations on the floor and, depending on the aim of the test, at the man-seat interface (and optionally at the man-back interface).

The term “measuring equipment” used hereafter refers to a set of devices which makes it possible to measure and to record the signals. The signals (whether recorded or in real time) may be subject to further processing which is described in clause 6.

NOTE In many applications, part of the signal analysis is carried out during the measurement, before the measured signals are recorded. This activity is called “pre-processing”.

In this International Standard “method of measurement” refers to the ways in which the measuring equipment is applied in order to collect the data which are the subject of the tests to be carried out.

5.2 Measuring equipment

5.2.1 General

The measuring equipment normally consists of

— transducers (accelerometers) and some conditioning amplifiers,

— filters (band limitation and frequency weighting) and measuring amplifiers, and

— recorders.

This set of equipment forms a measuring chain.

The characteristics of the equipment should be consistent. The accuracy of the measuring chain is defined by the characteristics of the individual components as well as by certain characteristics of the complete measuring chain.

5.2.2 Transducers and conditioning amplifiers

Since in many cases it is not possible to separate the transducer and conditioning amplifier, these two devices should be treated together and should meet the following conditions:

— minimum measuring range: floor: 0 to 50 m/s^2,

man-seat and man-back interface: 0 to 20 m/s^2;

— minimum frequency range: 0,4 Hz to 100 Hz (flat to within ± 0,5 dB);

— non-linearity plus hysteresis: $\leqslant$ 1 % of the measured value;

— cross axis sensitivity: $\leqslant$ 5 %;

— effect of temperature: on zero: $\leqslant$ 3 % of the measuring range,

on sensitivity: $\leqslant$ 0,05 % per degree Celsius.

5.2.3 Band-limiting and frequency-weighting filters

To eliminate very-low-frequency as well as too-high-frequency components which are not in the range of vibration relevant to this International Standard, and also to improve the measuring signal-to-noise ratio, band-pass filters should be used.

Lower and upper frequency band limitation shall be achieved by at least two-pole high-pass and low-pass filters, respectively, with Butterworth characteristics, having therefore an asymptotic slope of at least 12 dB per octave. The corner frequencies of the band-limiting filters are one-third octave outside the nominal frequency band.

Within the nominal frequency band and one-third octave from the frequency limits, the tolerance of the combined frequency weighting and band limiting is ± 1 dB. Outside this range, the tolerance is ± 2 dB. One octave outside the nominal frequency band, the attenuation may extend to infinity. (For tolerances, see also ISO 8041.)

5.2.4 Recorders

Recorders should meet the following specifications:

a) FM recorders

— minimum frequency range: 0 to 156 Hz,

— cut-off frequency: 156 Hz (– 0,5 dB);

b) PCM recorders

— minimum frequency range: 0 to 128 Hz;

c) digital recorders (recording to a digital medium)

— minimum frequency range: 0 to 128 Hz.

If PCM recorders or digital recording are used, anti-aliasing filters shall be used. (Usually these filters are built into the recorders.)

5.3 Measurement location

The acceleration shall be measured on the floor and, depending on the aim of the test, at the man-seat interface (and optionally at the man-back interface). The acceleration at a given point in a railway vehicle is dependent on the position of this point in the vehicle. Therefore the measurements should be carried out at the following locations:

— on the floor: over the bogie centre(s) and, optionally, at the centre of the vehicle body, and, depending on the aim of the test, on the vestibule floor;

— for seating position if investigated: on and under seats at the centre and, optionally, at both ends of the vehicle body.

In the driver's cabin, the measurement should be carried out near the place where the seat is mounted.

The accelerometers should be mounted on the floor as close as possible (less than 100 mm if possible) to the vertical projection of the centre of the seat pan, and on the vestibule floor when studying the standing position for local transport.

Other measurement locations may be used depending on the particular aim of the test.

5.4 Measurement directions

The coordinates of the human body are those defined in Figure 1 in accordance with ISO 2631-1. However, a human body-centred coordinate system is not always well suited for characterizing the comfort or motion relationship in railway environments. ISO 2631-4 therefore defines the following alternative coordinate system when measuring at the car structure (floor):

— z-axis: vertical, upwards perpendicular to the floor;

— x-axis: longitudinal, along the direction of travel;

— y-axis: lateral at right angle to the direction of travel.

