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Second edition
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Mechanical vibration — Road surface profiles — Reporting of measured data

Vibrations mécaniques — Profils de routes — Méthode de présentation des résultats de mesures

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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).

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The committee responsible for this document is ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*.

This second edition cancels and replaces the first edition (ISO 8608:1995), of which it constitutes a minor revision. The following changes have been made:

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— normative references have been updated;

— subclause numbering has been adjusted;

— figures have been made language independent;

— bibliography has been updated;

— editorially revised.

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Introduction

The purpose of this document is to facilitate the compilation and comparison of measured vertical road profile data from various sources. It therefore specifies a uniform method of reporting data from one-track and multiple-track measurements.

It specifies how measurements are to be reported, but not how the measurements are to be made. The measuring equipment can influence the results of the measurement; therefore certain characteristics of the measuring system have also to be reported.

Annex A is an example of a report which meets the minimum requirements of this document.

Annex B gives means of approximately characterizing specific road profiles in order to facilitate the division of road profiles into general classifications. A general classification is also given. A curve fitting method is presented for characterizing spectral data.

Annex C provides general guidance for the use of road profile statistical data for simulation studies and for related studies such as evaluation of comfort, suspensions and road profiles.

Annex D discusses the processing of the power spectral density (PSD) with the fast Fourier transform (FFT) technique. A discussion on the statistical precision is also given.

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Mechanical vibration — Road surface profiles — Reporting of measured data

1 Scope

This document specifies a uniform method of reporting measured vertical road profile data for either one-track or multiple-track measurements.

It applies to the reporting of measured vertical profile data taken on roads, streets and highways, and on off-road terrain. It does not apply to rail-track data. Measurement and processing equipment and methods are not included.

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.

IEC 61260-1, *Electroacoustics — Octave-band and fractional-octave-band filters — Part 1: Specifications*

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3 Terms and definitions

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

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

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

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
spatial frequency
reciprocal of the wavelength

Note 1 to entry: The spatial frequency is expressed in cycles per metre (cycles/m).

3.2
power spectral density
PSD
limiting mean-square value of a signal per unit frequency bandwidth

Note 1 to entry: For a one-sided spectrum, the area located between the graphic plot and the horizontal axis in a linear plot should be equal to the variance σ^2 of the original signal for the evaluated frequency range. This leads to a doubling of the spectral amplitude when the calculation process is only estimating the spectrum for positive frequencies.

3.3
displacement PSD
power spectral density of the vertical road profile displacement

3.4
velocity PSD
power spectral density of the rate of change of the vertical road profile displacement per unit distance travelled (slope of the vertical road profile)

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3.5
acceleration PSD
power spectral density of the rate of change of the slope of the vertical road profile per unit distance travelled

3.6
decolouring
procedure to eliminate the influence of the transfer function of the measuring system on the power spectral density

Note 1 to entry: The raw power spectral density should be decoloured before any further processing by dividing it by the square of the modulus of the measuring equipment transfer function.

3.7
smoothing
averaging process in which a data block is shifted and averaged

Note 1 to entry: In this document, “unsmoothed PSD” means the power spectral density as calculated from the measured data, i.e. with the bandwidths used in or following from the calculations and which are different from those indicated in Table 2. The term “smoothed PSD” is the power spectral density which is obtained after using the averaging process described in 5.1.2.

4 Symbols

The symbols used in this document are given in Table 1.

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Table 1 — Symbols

Symbol	Description	Unit
B_e	Frequency resolution	cycles/m
f	Time frequency	Hz
$G_d(.)$	Displacement PSD	m^3
$G_v(.)$	Velocity PSD	m
$G_a(.)$	Acceleration PSD	m^{-1}
$G_1(.)$	PSD of track 1	—
$G_2(.)$	PSD of track 2	—
$G_{12}(.)$	Cross spectrum between tracks 1 and 2	—
l	Wheelbase	m
n	Spatial frequency	cycles/m
t	Time	s
v	Vehicle speed	m/s
γ^2	Coherence function	—
σ^2	Variance	
ω	Angular frequency (= $2\pi f$)	rad/s
Ω	Angular spatial frequency (= $2\pi n$)	rad/m
NOTE The indication (.) means that the parameter of the function can be spatial frequency (n) or angular spatial frequency (Ω).		

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5 Uniform method of reporting

5.1 One-track data

5.1.1 Description of the road profile

5.1.1.1 General

The road profile shall be described by one or both of the following methods, with preference for the first, the displacement PSD.

The reporting of the non-smoothed data is always required.

5.1.1.2 First method — Displacement PSD: $G_d(.)$

The road profile shall be described by the power spectral density (PSD) of its vertical displacement. The report shall include the displacement PSD versus (angular) spatial frequency, both on logarithmic axes. The dimensions are metres cubed (m^3) versus reciprocal metres (cycles/m and rad/m).

Two scales shall be given on the ordinate, one for $G_d(n)$ and one for $G_d(\Omega)$. Both n and Ω scales shall be indicated in the abscissa. The grid, however, shall only be drawn for $G_d(n)$ and n (see Figure A.2, for example).

5.1.1.3 Second method — Acceleration PSD: $G_a(.)$

The acceleration power spectral density (PSD) is an allowed alternative method of reporting data.

In this case, the road profile shall be described as the PSD of its acceleration in terms of the rate of change of the slope of the road surface per unit distance travelled. The dimension of the acceleration PSD is reciprocal metres (m^{-1}).

The scales shall be logarithmic on both axes. Two scales shall be given on the ordinate, one for $G_a(n)$ and one for $G_a(\Omega)$. On the abscissa, both n and Ω shall be indicated. The grid, however, shall only be drawn for $G_a(n)$ and n.

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5.1.1.4 Relationship between the two reporting methods

The relationship between the two reporting methods (see 5.1.1.2 and 5.1.1.3) is given by Formulae (1) and (2):

$$G_a(n) = (2\pi n)^4 \cdot G_d(n) \tag{1}$$

$$G_a(\Omega) = \Omega^4 \cdot G_d(\Omega) \tag{2}$$

5.1.1.5 Spatial frequency range

The reported PSD shall be restricted between the limits allowed by the measuring equipment. For the report, the user may select any spatial frequency range appropriate to his/her particular road surface, problem and product.

The measured surface depends on the measuring equipment, which has a certain smoothing effect. This equipment is to be reported (see Note 4 and 5.3.5.2.1).

NOTE 1 Figure C.1 gives the relationship between the vehicle speed, the spatial frequency and the time frequency. Knowledge of the frequency and speed characteristics for a given class of vehicles makes it possible to choose the useful limits for that class of vehicle (e.g. on-road or off-road vehicles).

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NOTE 2 For the lower limit, the spatial frequency need not in general be measured lower than 0,01 cycles/m for on-road vehicles and 0,05 cycles/m for off-road vehicles.

NOTE 3 The enveloping effect of the tyre acts as a low-pass filter for the road vibration input to the vehicle. This effect depends on the size and construction of the tyre. For general on-road measurements, this results in a recommended upper limit of 10 cycles/m. Of course for suspension vibration purposes, the interesting upper limit depends on the maximum allowed speed on the particular road. For noise purposes, the interesting upper limit may be much higher, and may go as high as 1 000 cycles/m.

NOTE 4 Due to the tyre width there is also an enveloping effect in the lateral direction. This means that for vibration purposes, the mean of the footprint is usually measured. The width depends on the problem (e.g. vibration, noise) and the product (e.g. motorcycle tyres, truck tyres). For general on-road measurements not intended for a specific product, a track of about 100 mm wide is often used for vibration purposes. For noise purposes, a point measurement is often used.

NOTE 5 For off-road measurements, care needs to be taken when interpreting the high frequencies. For soft (e.g. sandy) surfaces, short undulations could be flattened by the wheel load and filtered out. For hard (e.g. stone) surfaces, however, only the enveloping effect of the tyre acts as a filter. In this situation, the surface needs to be described accurately in the data sheet (see 5.3.5.3.2).

NOTE 6 Annex B gives recommended methods for the characterization of the road profile and for the fitting of the measured data.

5.1.2 Presentation of the smoothed power spectral density

When the power spectral densities are calculated with a constant bandwidth method, their representation in a log-log diagram give an appearance or visual impression at high frequencies which over-emphasizes the fluctuations of the PSD generated by the real power distribution and by the statistical noise.

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For this reason, the PSD shall also be represented in a smoothed form, i.e. by the mean PSD in the following frequency bands:

— octave bands from the lowest calculated frequency (except zero) up to a centre frequency of 0,031 2 cycles/m (0,196 3 rad/m);

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— one-third-octave bands from the last octave band up to a centre frequency of 0,25 cycles/m (1,570 8 rad/m);

— for the rest of the frequency range, one-twelfth-octave bands up to the highest calculated frequency.

The centre frequencies to be used for the calculation of the smoothed PSD are given in Table 2.

Table 2 — Centre frequencies and cut-off frequencies for PSD smoothing, expressed in spatial frequency *n*

Exponent EXP	**Lower cut-off frequency** n_l cycles/m	**Centre frequency** $n_c = 2^{EXP}$ cycles/m	**Upper cut-off frequency** n_h cycles/m
Octave bands			
−9	0,001 4	0,002 0	0,002 8
−8	0,002 8	0,003 9	0,005 5
−7	0,005 5	0,007 8	0,011 0
−6	0,011 0	0,015 6	0,022 1
−5	0,022 1	0,031 2	0,044 2

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Table 2 *(continued)*

Exponent EXP	**Lower cut-off frequency** n_l cycles/m	**Centre frequency** $n_c = 2^{EXP}$ cycles/m	**Upper cut-off frequency** n_h cycles/m
One-third-octave bands			
−4,333	0,044 2	0,049 6	0,055 7
−4	0,055 7	0,062 5	0,070 2
−3,667	0,070 2	0,078 7	0,088 4
−3,333	0,088 4	0,099 2	0,111 4
−3	0,111 4	0,125 0	0,140 3
−2,667	0,140 3	0,157 5	0,176 8
−2,333	0,176 8	0,198 4	0,222 7
−2	0,222 7	0,250 0	0,280 6
One-twelfth-octave bands			
−1,833	0,272 6	0,280 6	0,288 8
−1,750	0,288 8	0,297 3	0,306 0
−1,667	0,306 0	0,315 0	0,324 2
−1,583	0,324 2	0,333 7	0,343 5
−1,500	0,343 5	0,353 6	0,363 9
−1,417	0,363 9	0,374 6	0,385 6
−1,333	0,385 6	0,396 9	0,408 5
−1,250	0,408 5	0,420 4	0,432 8
−1,167	0,432 8	0,445 4	0,458 5
−1,083	0,458 5	0,471 9	0,485 8
−1	0,485 8	0,5	0,514 7
−0,917	0,514 7	0,529 7	0,545 3
−0,833	0,545 3	0,561 2	0,577 7
−0,750	0,577 7	0,594 6	0,612 0
−0,667	0,612 0	0,630 0	0,648 4
−0,583	0,648 4	0,667 4	0,687 0
−0,500	0,687 0	0,707 1	0,727 8
−0,417	0,727 8	0,749 2	0,771 1
−0,333	0,771 1	0,793 7	0,817 0
−0,250	0,817 0	0,840 9	0,865 5
−0,167	0,865 5	0,890 9	0,917 0
−0,083	0,917 0	0,943 9	0,971 5
0	0,971 5	1	1,029 3
0,083	1,029 3	1,059 5	1,090 5
0,167	1,090 5	1,122 5	1,155 4
0,250	1,155 4	1,189 2	1,224 1
0,333	1,224 1	1,259 9	1,296 8
0,417	1,296 8	1,334 8	1,374 0
0,500	1,374 0	1,414 2	1,455 7
0,583	1,455 7	1,498 3	1,542 2
0,667	1,542 2	1,587 4	1,633 9

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Table 2 *(continued)*

Exponent EXP	**Lower cut-off frequency** n_l cycles/m	**Centre frequency** $n_c = 2^{EXP}$ cycles/m	**Upper cut-off frequency** n_h cycles/m
0,750	1,633 9	1,681 8	1,731 1
0,833	1,731 1	1,781 8	1,834 0
0,917	1,834 0	1,887 7	1,943 1
1	1,943 1	2	2,058 6
1,083	2,058 6	2,118 9	2,181 0
1,167	2,181 0	2,244 9	2,310 7
1,250	2,310 7	2,378 4	2,448 1
1,333	2,448 1	2,519 8	2,593 7
1,417	2,593 7	2,669 7	2,747 9
1,500	2,747 9	2,828 4	2,911 3
1,583	2,911 3	2,996 6	3,084 4
1,667	3,084 4	3,174 8	3,267 8
1,750	3,267 8	3,363 6	3,462 1
1,833	3,462 1	3,563 6	3,668 0
1,917	3,668 0	3,775 5	3,886 1
2	3,886 1	4	4,117 2
2,083	4,117 2	4,237 9	4,362 0
2,167	4,362 0	4,489 8	4,621 4
2,250	4,621 4	4,756 8	4,896 2
2,333	4,896 2	5,039 7	5,187 4
2,417	5,187 4	5,339 4	5,495 8
2,500	5,495 8	5,656 9	5,822 6
2,583	5,822 6	5,993 2	6,168 8
2,667	6,168 8	6,349 6	6,535 7
2,750	6,535 7	6,727 2	6,924 3
2,833	6,924 3	7,127 2	7,336 0
2,917	7,336 0	7,551 0	7,772 3
3	7,772 3	8	8,234 4

NOTE A small overlap exists between the lowest one-twelfth-octave band and the highest one-third-octave band. This overlap maintains the values 0,5; 1; 2; 4 as centre frequencies in the one-twelfth-octave bands. This makes it convenient to calculate the road characterization (see B.4) immediately from the one-twelfth-octave band smoothing.

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