



SLOVENSKI STANDARD

SIST EN 15433-4:2008

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Transportation loads - Measurement and analysis of dynamic mechanical loads - Part 4:
Data evaluation

Transportbelastungen - Messen und Auswerten von mechanisch-dynamischen
Belastungen - Teil 4: Datenauswertung

Charges de transport - Mesurage et analyse des charges mécaniques dynamiques -
Partie 4 : Evaluation des données

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English Version

Transportation loads - Measurement and evaluation of dynamic mechanical loads - Part 4: Data evaluation

Charges de transport - Mesurage et analyse des charges
mécaniques dynamiques - Partie 4: Evaluation des
données

Transportbelastungen - Messen und Auswerten von
mechanisch-dynamischen Belastungen - Teil 4:
Datenauswertung

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Foreword

This document (EN 15433-4:2007) has been prepared by Technical Committee CEN/TC 261 “Packaging”, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2008, and conflicting national standards shall be withdrawn at the latest by June 2008.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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Introduction

This standard was originally prepared by working group NAVp-1.4, Requirements and Testing, of the German Standardization Institute (DIN). It is part of a complete normative concept to acquire and describe the loads acting on goods and influencing them during transport, handling and storage.

This standard becomes significant when related to the realisation of the European Directive on Packaging and Packaging Waste (Directive 94/62 EC, 20 December 1994). This directive specifies requirements on the avoidance or reduction of packaging waste, and requires that the amount of packaging material is adjusted to the expected transportation load, in order to protect the transportation item adequately. However, this presumes some knowledge of the transportation loads occurring during shipment.

At present, basic standards, based on scientifically confirmed values, which can adequately describe and characterize the magnitudes of transportation loads, especially in the domain of dynamic mechanical loads do not exist nationally or internationally. Reasons for this are mainly the absence of published data, insufficient description of the measurements or restrictions on the dissemination of this information.

This standard will enable the measurement and evaluation of dynamic mechanical transportation loads, thus enabling the achievement of standardized and adequately documented load values.

This series of standards consists of the following parts:

- Part 1: General requirements,
- Part 2: Data acquisition and general requirements for measuring equipment;
- Part 3: Data validity check and data editing for evaluation;
- Part 4: Data evaluation;
- Part 5: Derivation of Test Specifications;
- Part 6: Automatic recording systems for measuring randomly occurring shock during monitoring of transports.

1 Scope

This standard presents guidelines for the instruments, procedures and parameters, used to analyse dynamic data. It is assumed that the person performing the analyses has the use of appropriate digital FFT signal processors or FFT computers.

These guidelines are also applicable for other types of signal processing procedures, as long as the analysing parameters are equivalent. Such other procedures contain correlation algorithms e.g. Blackman-Tuckey), digital band pass filter algorithms or heterodyne techniques.

An outline of the data analysis procedures covered in this section is presented in Figure 1.

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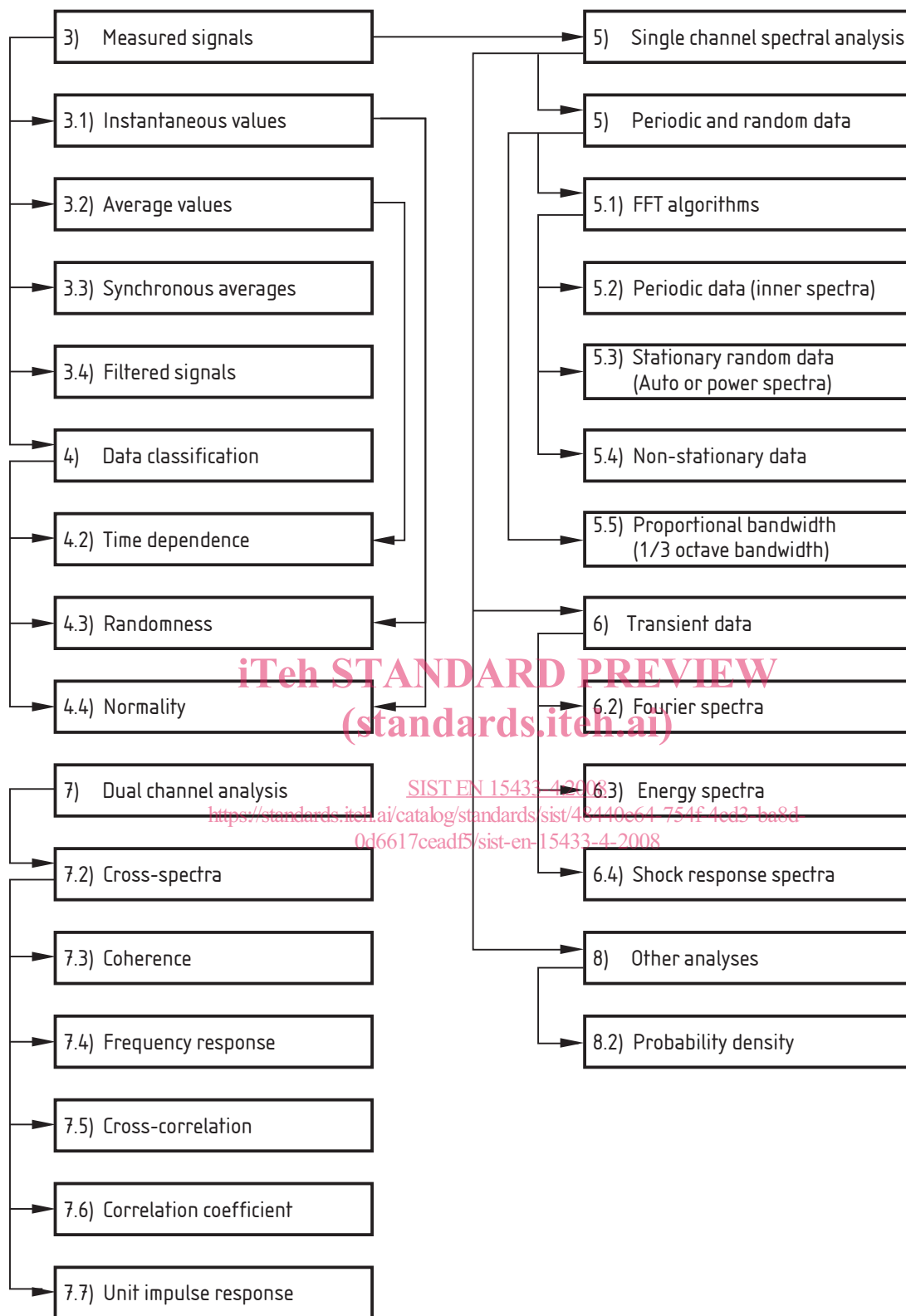


Figure 1 — Outline of data analysis

2 Normative references

The following referenced documents are indispensable for the application 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.

Not applicable.

3 Measured signals

NOTE The signal analysis procedures discussed in Clause 3 are in addition to the evaluations described in EN 15433-3 for the purpose of data validity checking and data editing for evaluation.

3.1 Instantaneous values

Beyond the purpose of data validation and editing, certain applications may require an evaluation of instantaneous signal values. In particular, the general design of structures for low frequency loads is commonly based upon maximum value estimates made from signal time histories.

3.2 Average values

3.2.1 General

The most common average values measured in stationary signals are the mean value μ_x and the standard deviation σ_x (or the rms value ψ_x). Estimates of the mean value and standard deviation of a signal $x(t)$, where $0 \leq t \leq T$, may be computed with the aid of the following algorithms:

a) Mean value: $\hat{\mu}_x = \frac{1}{T} \int_0^T x(t) dt = \frac{1}{N} \sum_{n=1}^N x(n\Delta t)$ (1)

b) RMS value: $\hat{\psi}_x = \left\{ \frac{1}{T} \int_0^T x^2(t) dt \right\}^{1/2} = \left\{ \frac{1}{N} \sum_{n=1}^N x^2(n\Delta t) \right\}^{1/2}$ (2)

c) Standard deviation:
$$\hat{\sigma}_x = \left\{ \frac{1}{T} \int_0^T [x(t) - \hat{\mu}_x]^2 dt \right\}^{1/2} = \left\{ \frac{1}{(N-1)} \sum_{n=1}^N [x(n\Delta t) - \hat{\mu}_x]^2 \right\}^{1/2} \quad (3)$$

where

T is the linear averaging time for analogue signals;

N is the number of data values for digital signals ($T = N\Delta t$);

($\hat{\cdot}$) denotes "estimate of".

NOTE For most high-frequency dynamic measurements, the transducer does not sense the static or DC component of the signal, whereas for most low frequency measurements (below 50 Hz), the DC component is included.

Without the DC component, the mean value of the signal is zero and the RMS value computation of equation (2) will yield the standard deviation.

3.2.2 Instruments and software

The averaging time constant is a key parameter in establishing the accuracy of average value estimates for random signals. The operations in equations (1) to (3) are easily accomplished on a digital computer with simple software programs.

NOTE Both analogue and digital DC voltmeters essentially compute the mean value of a signal, while true RMS voltmeters (not to be confused with AC voltmeters) compute an approximation of the RMS value of a signal.

Most analogue and digital voltmeters compute a continuous exponential weighted (RC) average, rather than a single linear average.

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3.2.3 Types of averaging

Various methods are common for computing average values. The procedures and parameters used to perform the computation should be detailed.

In the case of stationary or steady state signals (where the average value of interest does not change much over the duration of the measurement), a linear average over the entire measurement is recommended.

In the case of non-stationary signals (where the average value of interest is changing considerably over the measurement duration), an exponential weighted average is recommended for analogue signals, and a step-wise linear average is recommended for digital signals.

NOTE A step-wise linear average (sometimes called a running average) can be produced by computing a series of average value estimates using N data values, where n new values are added to the end and n old values are discarded from the beginning of the N data values for each average. This will produce correlated average value estimates every Δt seconds ($n = 1, N$).

3.2.4 Averaging time and sampling errors

For periodic signals, the only error in an average value estimate (beyond calibration errors) is the truncation error caused by the fact that the averaging operation may not cover an exact integer number of cycles of the signal. This truncation error becomes negligible as the linear averaging time becomes long relative to the period of the signal.

For random signals, however, there will be a random sampling error in the average value estimate that is dependent on both the averaging time and the frequency bandwidth of the signal.

The normalized random error ε_r in the estimate of a parameter Φ is defined as:

$$\varepsilon_r[\hat{\Phi}] = \frac{\sigma[\hat{\Phi}]}{\Phi} \quad (4)$$

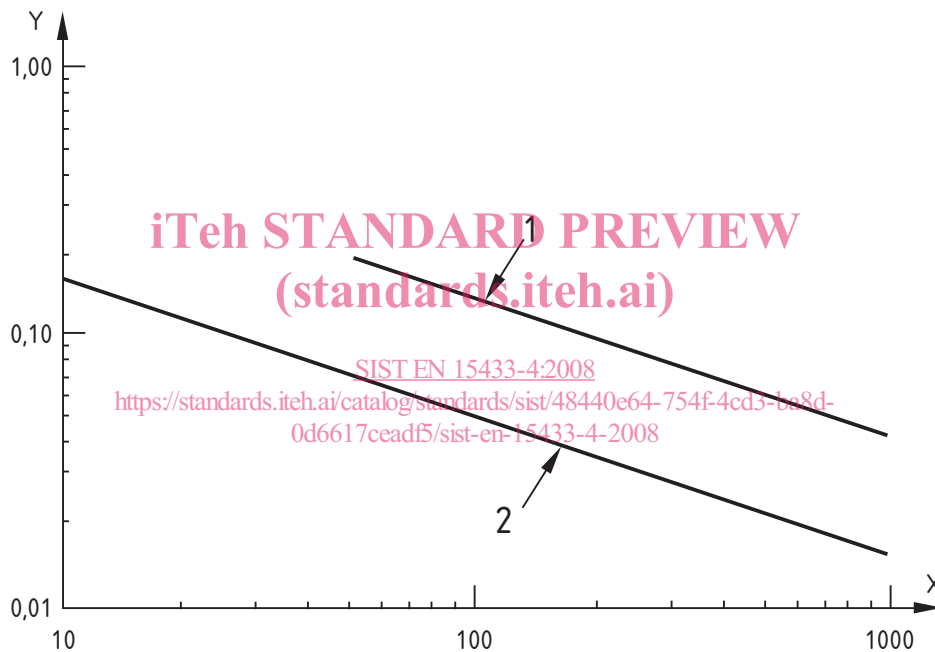
where

$\sigma[\hat{\Phi}]$ is the standard deviation of the estimate $\hat{\Phi}$.

NOTE The random errors for the estimates of the mean and RMS values of random signals are summarized in Figure 2 in terms of a normalized random error (coefficient of variation).

The quantity B in Figure 2 is the frequency bandwidth of the signal, assumed to have a uniform spectrum, and the quantity T is the linear averaging time used to make the estimate.

In the case of exponentially weighted averages with a time constant K , it can be assumed from Figure 2 that $T = 2K$.



Key

X-axis For mean values: $BT/(\sigma/\mu)^2$; For RMS values BT

Y-axis Normalised random error ε_r

1 Mean value: $\varepsilon_r = (2/BT)^{1/2} (\sigma/\mu)$

2 RMS value ($\mu=0$): $\varepsilon_r = 0,5/(BT)^{1/2}$

Figure 2 — Normalized random errors for mean and mean square value estimates

3.3 Synchronous averaging

3.3.1 General

Reciprocating and rotating machinery operating under steady-state conditions produce periodic components (i.e. signals that exactly repeat themselves after a time interval T_1 , called the period) such that:

$$p(t) = p(t + iT_1); i = 1, 2, 3, \dots \quad (5)$$

However, the periodic signal of interest is sometimes contaminated by random background noise and/or independent data signals, producing a measured signal $x(t) = p(t) + n(t)$, where $n(t)$ is the noise and/or other independent signal.

In such cases, the signal-to-noise level of the periodic signal of interest should be enhanced by the procedure of synchronous averaging, where the measurement is divided into a collection of segments $x_i(t)$; $i = 1, 2, \dots, q$, each starting at exactly the same phase angle during a period of $p(t)$.

The collection of segments can be ensemble averaged to extract $p(t)$ from background noise, as well as other periodic components which are not harmonically related to $p(t)$, as follows:

$$p(t) \approx \frac{1}{q} \sum_{i=1}^q x_i(t) \quad (6)$$

3.3.2 Instruments and software

Many of the modern special-purpose signal processing computers produced for dynamic signal analyses provide a synchronous averaging mode.

A trigger signal should be provided to the analyser that will initiate new signal segments at a desired instant during a period $p(t)$. The averaging may be accomplished directly on the signal segments, or in the frequency domain on the Fourier transforms of the segments.

3.3.3 Triggering procedures

Synchronous averaging is most effective when the trigger signal is a noise-free indicator of the phase during each period $p(t)$.

The time base accuracy of the trigger signal determines the accuracy of the magnitude of the resulting synchronous averaged signal, i.e. time base errors in the signal cause a reduction in the indicated signal amplitude with increasing frequency.

3.3.4 Signal-to-noise enhancement

The signal-to-noise level enhancement for a synchronous averaged signal is shown in Figure 3, where q is the number of segments used in the ensemble averaging operation.

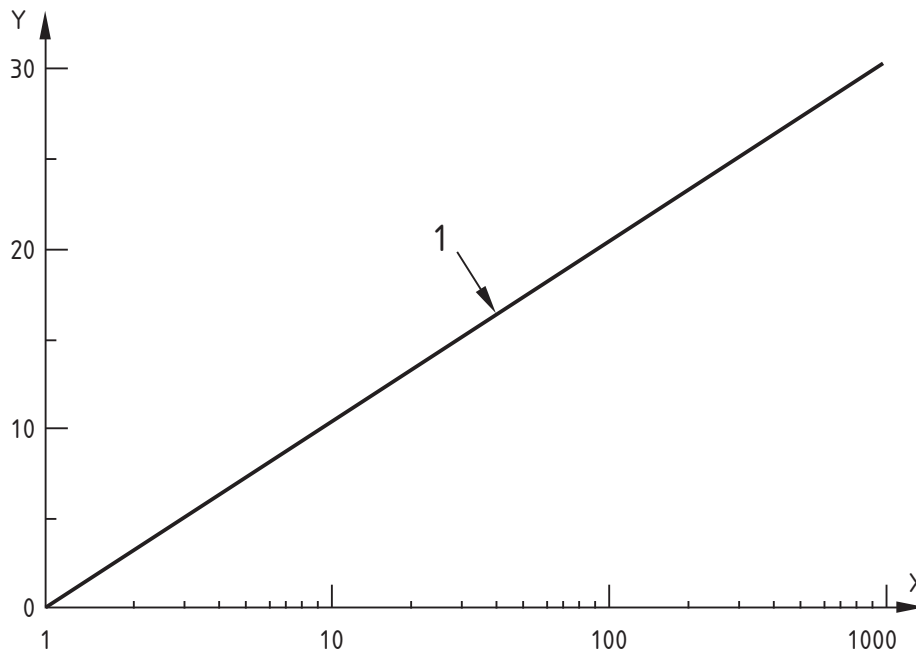
Letting σ_x and σ_n be standard deviations of the signal and noise, respectively, the signal-to-noise level enhancement in decibels is defined as:

$$S/N_e = 10 \log_{10} [SNR_a / SNR_b] \quad (7)$$

where

SNR_a = $(\sigma_x / \sigma_n)^2$ after the synchronous averaging;

SNR_b is the same ratio before the synchronous averaging.

**Key**X-axis Number of segments q

Y-axis Signal to noise level enhancement, dB

1 $S/N = 10 \log_{10} q$

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Figure 3 — Signal-to-noise level enhancement with synchronous averaging**3.4 Filtered signals**

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3.4.1 General

The detailed characteristics of the preferred filters should be known, and their possible consequences on the interpolations of the resulting signals should be carefully assessed.

NOTE Vibration data are often acquired over a wider frequency range than may be of interest for certain applications. It is common in such applications to low pass filter the signals to obtain time histories representing only the low frequency portion of the signal. In a large number of cases, the low frequency signals are digitized and used as inputs to finite element computations.

The practice of defining maximum low frequency loads using low pass filtered signals involves a subjective judgement in that the resulting signal is heavily dependent on the cut-off frequency, roll-off rate and phase shift of the low pass filters.

Occasionally, dynamic data signals are high pass filtered to AC couple the data.

3.4.2 Analogue filtering

The simplest way to limit the frequency range of a signal is to low pass filter the analogue signal directly.

If the signal is to be later digitized, the low pass filtering can be easily accomplished using the anti-aliasing filter for the A/D converter.

NOTE Many analogue anti-aliasing filters introduce a non-linear phase shift near the filter cut-off frequency that may distort the signal time history.