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BSI Standards Publication

Transportation loads — Measurement and evaluation of dynamic-mechanical loads

Part 6: Automatic recording systems for measuring randomly occurring shock during monitoring of transports

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National foreword

This British Standard is the UK implementation of EN 15433-6:2016. It supersedes BS EN 15433-6:2007 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PKW/0, Packaging.

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Contents

Page

European foreword

This document (EN 15433-6:2016) 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of an identical text or by endorsement, at the latest by January 2017, and conflicting national standards shall be withdrawn at the latest by January 2017.

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Introduction

This standard becomes significant when related to the realization of the European Directive on Packaging and Packaging Waste (Directive 94/62 EC, 20th December 1994), as amended by the Directive 2005/20/EC of 9th March 2005. 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 analysis 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.

This standard defines requirements that should be observed when automatic recording systems are being used for the purpose of a transportation survey. In this, it deviates from the characteristics of the other parts of the series, as in this case the prime concern is not the need for scientifically based and generally applicable data, which are to be used for standardization purposes, but to assist users of “shock recorders“. Such automatic and computer-based recording systems have gone through remarkable developments, particularly in relation to their storage capacity and analysis capability. This, together with falling prices, has meant they are increasingly used for surveying specific transportations, especially inside packing. In general they do not reach the efficiency of a measuring chain such as used for test drives, especially in view of the storage capacity needed to measure unfiltered dynamic data during transportation.

1 Scope

This European Standard specifies the technical and functional properties of automatic recording equipment used to determine randomly appearing shocks during transportation.

Such automatic recording equipment can be used to:

— determine mechanical shock loads on individual transportations;

— monitor the transportation means to observe the limits of the shock parameters;

— determine the shock loads on the transported item.

This standard defines the sensors to be attached to the device, and specifies the minimum requirements for the parameters to be adjusted. It also defines the minimum requirements for the data analysis, as well as the data presentation.

This standard covers the complete recording equipment, including its accelerometers and the data analysis in an external data processing unit. The accelerometers can be integrated into the device or separately mounted from it (external sensors).

This standard also applies to the routine monitoring of individual transportations

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 13011, *Transportation services - Good transport chains - System for declaration of performance conditions*

EN 15433-2, *Transportation loads - Measurement and evaluation of dynamic mechanical loads - Part 2: Data acquisition and general requirements for measuring equipment*

EN 61000-6-1, *Electromagnetic compatibility (EMC) - Part 6-1: Generic standards - Immunity for residential, commercial and light-industrial environments*

EN 61000-6-3, *Electromagnetic compatibility (EMC) - Part 6-3: Generic standards - Emission standard for residential, commercial and light-industrial environments*

EN 60529, *Degrees of protection provided by enclosures (IP Code)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply

3.1
sensor axes *x, y, z*
three Cartesian spatial axes that lie parallel to the measuring directions of the accelerometer

3.2
peak acceleration value
greatest positive or negative acceleration occurring during a shock event in a spatial axis or in a spatial vector: $\hat{a}_x$, $\hat{a}_y$, $\hat{a}_z$, $\hat{a}_R$

3.3
main axis *xyz* (max.)
spatial axis that shows the biggest peak acceleration value

Note 1 to entry: Correspondingly $a_{xyz(max)}$ is the temporal course of the acceleration of the main axis and $\hat{a}_{xyz(\max)}$ is the peak acceleration of the main axis.

3.4
value of the spatial vector a_R
acceleration value of a randomly oriented spatial acceleration vector of a shock event

$$a_R = \sqrt{a_x^2 + a_y^2 + a_z^2} \quad (1)$$

3.5
shock duration T_{shock}
time at which the value of the acceleration of the main axis is equal to or greater than 10 % of the peak acceleration value of this axis

Note 1 to entry: See 4.3.1.

3.6
frequency limit of the device
frequency at which the recorded signal level has dropped to a value of $1/\sqrt{2}$ compared to the mid-band frequency; this information is compulsory to ensure that measured values of different devices are comparable

3.7
threshold values
magnitudes of the acquired measured values which when exceeded initiate the recording of an event: $a_{threshold}$, $T_{shock(min)}$

3.8
values to be set
sum of all adjustments made to a recording equipment prior to a measuring event (e.g. measuring range, frequency limit, threshold values, storing modes, time modes, recording type or mail box content)

3.9
mailbox
device able to store data in an alphanumeric order, e.g. tracing program, order of transport, transport information, or mounting location of recording equipment

3.10
data memory
all data memory of a recording equipment in which measured and computed values as well as acquisition time span and set values are stored

3.11
acquisition time span
continuous time span during which the recording equipment is active; the set values must be documented

Note 1 to entry: The beginning and end of an acquisition time span can be caused by switching on and off, set time modes, changing the set values, dropout of power supply, battery change, data evaluation or hardware errors.

3.12
time stamp
date and time of an event, minimum resolution in seconds

3.13
sampling rate
number of digital measuring values produced for each time unit and for each sensor axis

3.14
GPS value
location coordinates in the satellite-assisted Global Positioning System

3.15
tilt value
static measured value indicating the position of the transported item in relation to the axis of the earth

Note 1 to entry: The measured value can be indicated as an angle or an acceleration value. Any dynamic components caused by shocks or vibrations shall be filtered out.

3.16
shock intensity
equivalent velocity change
time integral over all measured acceleration values of one spatial axis or of the spatial vector within the shock duration T_{shock}

Note 1 to entry: See 4.3.1.

3.17
main shock direction
indication of a spatial axis with the greatest shock amplitude

Note 1 to entry: See 4.3.1.

4 Requirements for automatic recording devices

4.1 Accelerometers

Automatic shock recording equipment shall be equipped with three accelerometers arranged in a system of Cartesian axes, in order to record the acceleration acting in any direction.

Internal sensors are arranged inside the housing of the recording equipment.

External sensors shall be connected to the recording equipment by means of cables, such that no falsification of the measured values can occur.

The sensor axes shall be parallel or perpendicular to the edge of the recorder housing or the external sensor. The positive directions of the sensor axes shall be uniquely defined by arrows as well as by the designations *x, y, z*. When connecting external sensors, care shall be taken that no exchange of the axes or the direction of the measurement can occur.

The requirements to the measuring range (see 4.8) and environmental conditions (see 4.12) shall be observed.

4.2 Signal processing

Acceleration sensors have low pass or band pass behaviour. Their signals can further be processed in fixed or adjustable filters. The frequency limit, its characteristic and its order shall be declared. The declaration shall apply to the complete measuring chain.

The measuring range is defined by the greatest acceleration value processed, and shall be adjustable or adapted to a defined transportation load.

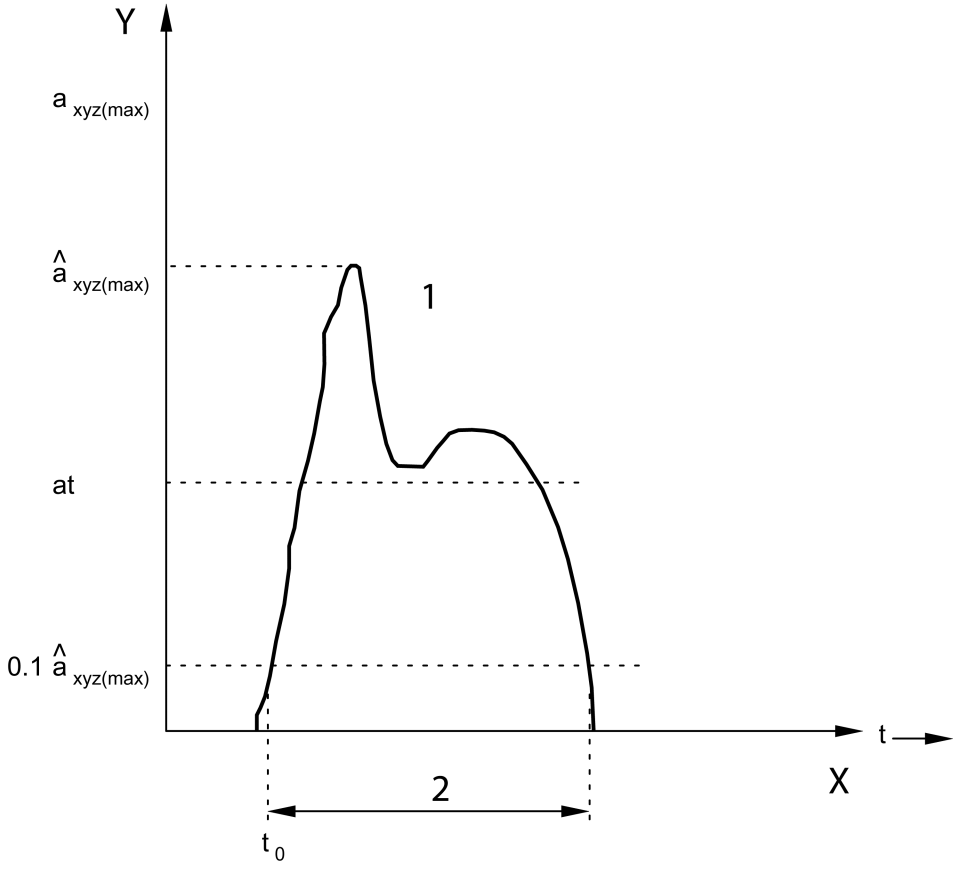
The signal processing as well as storage occurs digitally. The sampling rate shall be mentioned.

4.3 Recordings

4.3.1 Recording mode "event"

A random shock event occurs when the peak acceleration value in at least one spatial axis exceeds the set acceleration threshold value $a_{\text{threshold}}$ of that particular axis, and when the shock duration of that event is equal to or greater than the minimum shock duration $T_{\text{shock (min)}}$.

See Figure 1.



Key

x-axis	Time
Y-Axis	Acceleration
1	Shock event

at $a_{\text{threshold}}$

2 T_{shock}

Figure 1 — Shock event

The shock duration T_{shock} is defined as the duration at which the acceleration $a_{xyz(max)}$ is equal to or greater than 10 % of the peak value $\hat{a}_{xyz(\max)}$.

The digital memory of the recording device shall store:

— time stamp;

— peak acceleration values of the axes $\hat{a}_x, \hat{a}_y, \hat{a}_z$ with their corresponding operational signs;

— shock duration T_{shock}.

Further to this, magnitudes such as the peak acceleration value of the spatial vector and the time integral of the acceleration within the shock duration T_{shock} can be computed and stored both for the spatial vector and separately for each axis.

The time integral (shock intensity) corresponds with the velocity change of the shock event to which it is connected:

$$\Delta v = \int_{t_o}^{t_o + T_{shock}} a_{xyz(\max)} \cdot \mathrm{d}t \qquad (2)$$

NOTE The axis with the greatest amplitude is relevant for determining the shock duration. When it falls under the 10 % value, the event is considered to be over. If the threshold value continues to be exceeded or is exceeded again on any of the axes, a new event starts. A detailed analysis of such signal waveforms with a phase shift between the axes can only be performed on the basis of the curves. GPS location coordinates can be stored event-related if a suitable receiver is available. For online analysis methods, which are possible later on using evaluation software, see Clause 6.

4.3.2 Recording mode “plotter”

The sampled values a_x, a_y, a_z shall be stored successively in the memory of the device, corresponding to their scan sequence. The sampling interval and time stamp shall also be stored.

The sampling interval, the number of samples to be recorded and the recording duration per section are adjustable.

The plotting of a section during the plotter mode is triggered by the adjustable threshold value $a_{threshold}$. By selecting a pre-triggering time, the start of the recording can be set to a defined time ahead of the threshold crossing.

4.4 Storage modes

The measured values shall be filed into the device’s memory as follows:

— measurement and recording can be performed until the data memory is full;

— when the data memory is full, then those shock events are overwritten, which have the smallest acceleration peak values, the shortest shock durations or the smallest velocity changes (preferential variant). Simultaneously, the associated threshold will be increased.

4.5 Time code

The time span for operational readiness of the device shall be set depending on the application.

— measuring and recording start at the time the device is switched on;

— measuring and recording start at the pre-programmed starting time;

— measuring and recording take place between the pre-programmed start and pre-programmed stop;

— measuring and recording take place between the switching on of the device and at a pre-programmed stop.

4.6 Power supply

The power supply of the automatic recording equipment shall be autonomous and have sufficient reserve run time for the intended deployment. The power source may be integrated into the recording equipment or placed in an auxiliary box.

It shall be ensured that the power supply is continuously available.

Any limitation of application as a result of working temperature and battery type shall be made recognizable.

The minimum available duration of use with a new battery or a fully charged battery shall be indicated.

The actual still-available duration of use shall be indicated, together with each data output.

The primary power supply shall have no influence on the measuring results in the data memory.

4.7 Operating and display elements

The following operating and display elements can be performed either by elements on the recording device, via a data bus of a special processing unit (e.g. laptop/tablet/PC/PDA)

— input of adjustable values;

— indication of measured results;

— indication of remaining duration of use.

The recording device shall indicate when:

— measurement and recording are active;

— equipment is switched on, starting time is not yet reached, or stopping time is exceeded;

— data memory is full when operating in the storage mode: “measuring and recording until data memory is full“;

— device has been switched off automatically due to an exhausted power supply or is already operating on a low battery;

— hardware error has been detected by self-testing.

4.8 Measuring range

The acceleration measuring range for each axis shall be adapted to the respective measurement task. The lower frequency limit shall be equal to or smaller than 2 Hz. The upper frequency limit shall be equal to or greater than 512 Hz (in accordance with EN 13011). The filters defining the frequency limits shall be of at least 4th order.

The sampling rate shall be at least two times (to reduce frequency analysis errors, preferentially four times) the selected upper frequency limit of the filter. If the recording equipment is used for further measurements (e.g. oscillations) then the sampling rate shall be set accordingly.

It shall be possible to acquire shock durations within a minimum range of 1 ms to 1 s.

The adjustable threshold for the acceleration shall encompass the range between 5 % and 75 % of the measuring range.

When the temporal course of the shock event is semi-sinusoidal, the range of the shock duration shall be declared for the error limit to be maintained.

The data memory shall be able to record the largest 100 complete shock curves. If no pre-evaluation of the shock events is possible in the device, the data memory shall be designed much larger (at least 3000 records). If it is not possible to record the curve, it is necessary to indicate at least the shock intensity for each event.

NOTE See Annex A for example settings of the recording equipment.

4.9 Error limits

The acceleration measurement error shall not be greater than 5 % in the range of 0 °C to 40 °C and at mid-band frequency, and maximally 10 % over the whole temperature range.

The cross sensitivity of the accelerometers shall be declared. It shall not exceed 5 % of the measured value between each of the 3 axes.

4.10 Saving of data

The recorded measured values, the acquisition period, and the set values shall be protected against any changes and unauthorized access. This not only concerns the data stored in the recording device, but also the read-out values, which are stored as a system file (password protection).

Each piece of recording equipment shall have its individual equipment number, which is visibly attached and non-erasable stored in the equipment.

Data from the transportation surveillance (such as the tracing program, order of transportation, or location of the recording equipment), shall be stored in alphanumeric order in a mailbox.

4.11 Evidence of calibration

The evidence of calibration shall prove that the acceleration calibration can be traced back to the reference standard. The duration of the calibration validity shall be declared. The system shall be calibrated at least once every 24 months.

4.12 Environmental conditions

The housing of the recording equipment as well as the sensors shall comply with protection type IP - 65 in accordance with EN 60529.

The equipment properties concerning the electromagnetic compatibility shall comply with EN 61000-6-3 and EN 61000-6-1.

The minimum operating temperature range shall be –20 °C to 75 °C, with lithium batteries – 40 °C to 85 °C.

The safety margin against vibration and shock loads shall be at least five times the maximum measuring range.

5 Preparation for deployment

5.1 Mounting

The mounting location of the recording equipment (e.g. on cargo platform, packed item or transported item) depends on the type of surveillance task. The recording equipment shall be mounted on a rigid part of the test item, using the fixing means of the monitoring device. The mounted recording equipment (data recorder, external accelerometers) shall increase the mass of the item to be tested by not more than 10 %, in order to keep the influence of the dynamic behaviour as small as possible.

The recording equipment shall be mounted in such a way that:

— x-axis corresponds with the main driving direction;

— y-axis is lateral to the main driving direction;

— z-axis is perpendicular to the cargo platform.

The mounting of the recording equipment shall be documented in accordance with EN 15433-2.

5.2 Setting values

Before the beginning of transport surveillance, the following settings shall be documented, preferably using a log sheet in accordance with EN 15433-2:

— selection of axes to be surveyed;

— measuring range of each axis;

— measuring sensitivity of each connected external sensor;

— frequency range;

— recording threshold acceleration for each axis $a_{\text{threshold}}$;

— recording threshold duration $T_{\text{shock(min)}}$;

— recording mode “event“ and/or “plotter“;

— sampling rate, recording duration, and pre-triggering time for the recording mode “plotter“;

— selection of storage mode;

— selection of time modes;

— setting of the internal clock of the monitoring device (time stamp);

— GPS use yes/no

— minimum inputs to the mailbox: transportation order, identification of transportation means, mounting location.

The remaining deployment duration reported by the device shall also be observed and suitable batteries shall be used.

When selecting batteries, the applicable temperature range and the approved environmental conditions shall be considered.

CAUTION — Depending on their size, lithium batteries may be considered as dangerous goods and shall then be identified as such, and are subject to restrictions on use.

The actual parameters of the minimum settings result from the problems defined for the transportation to be surveyed.

Adjusted values shall be stored as a file under a name that enables them to be activated in the recording equipment at any time required.

The settings shall be documented in accordance with EN 15433-2, preferably in a log sheet.

6 Analysis

The measured values can be analysed directly in the recording device or using a processing unit (e.g. laptop, tablet, PC or PDA) requiring the data to be transferred to the processing unit. The transfer shall be secured at least by a checksum.

The most important settings and measured results of one application shall be compiled in a log sheet. The minimum information recorded shall be:

— equipment number;

— system time and date of the equipment at the start of the analysis;

— remaining deployment duration with the current set of batteries;

— setting values according to 5.2;

— total number of stored events, plotter sections and acquisition time spans;

— number of events exceeding pre-set limits. Such limit values can relate to e.g. the peak value of the spatial vector of the acceleration, the shock duration, and the velocity change;

— largest stored peak value of the spatial vector, including its time stamp;

— longest stored shock duration, including its time stamp;

— greatest velocity change experienced, including its time stamp;

— a list of the acquisition start and end times, including the time stamps, the cause of the termination and the related settings.

— chart containing the time stamps, the peak acceleration values of the monitored spatial axes and of the spatial vector, the shock durations and the velocity changes;

— chart that contains only those events for which the limit values have been exceeded;

— diagrams showing peak acceleration values of the monitored spatial axes and the spatial vector as a function of time. If more than one event can be found in an interval, which is identified by the width of the cursor, then these events shall be marked;

— temporal distribution of the shock events;

— classification of the shock events with regard to selected measured magnitudes;

— diagrams and charts of each section (curve), including a time stamp, which have been recorded with the recording mode “plotter“.

Measured values that have exceeded the measuring range shall be marked.

It shall be possible to export the measured results in a format that can be processed by other analysis programs (standard formats).

The analysis should preferably be documented in a log sheet in accordance with EN 15433-2.

The optimization of packing and means or routes of transportation may require further analysis functions:

— 8 octave frequency analysis in accordance with EN 13011.

— Frequency spectrum (FFT);

— Power spectral density (PSD);

— Shock response spectrum (SRS);

— Velocity response spectrum (VRS);

— Determination of the equivalent height of fall.

Annex A
(informative)

Example set-up of shock recording equipment

Table A.1 shows example settings of the shock recording equipment. For specific applications, it is critical that the settings should be set accordingly.

Table A.1 — Example set-up of a shock recording equipment

Type of transportation	**Operating means**	**Measuring range** m/s^2	**Shock duration** ms
Road e.g. potholes	Event/curve recording	100	5
Rail e.g. shunting shocks	Event recording	100	20
Sensitive machine, e.g. optical equipment	Event/curve recording	50	5
Fall shock test	Curve recording	1000	1

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