BRITISH STANDARD

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Mechanical shock — Testing machines — Characteristics and performance

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British Standards

National foreword

This British Standard is the UK implementation of ISO 8568:2007. It supersedes BS 7347:1990 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GME/21, Mechanical vibration, shock and condition monitoring, to Subcommittee GME/21/2, Vibration and shock measuring instruments and testing equipment.

A list of organizations represented on this committee can be obtained on request to its secretary.

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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 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 8568 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 6, *Vibration and shock generating systems*.

This second edition cancels and replaces the first edition (ISO 8568:1989), which has been technically revised.

Mechanical shock — Testing machines — Characteristics and performance

1 Scope

This International Standard specifies performance parameters and methods of inspection of mechanical shock-testing machines and gives guidelines for describing their characteristics. It is intended to ensure that the potential user of a particular shock-testing machine is provided with an adequate description of the characteristics of the machine, and also to give guidance on the selection of such machines.

This International Standard is applicable to the shock-testing machines that are used for demonstrating or evaluating the effect of shock conditions representative of the service environment in accordance with the relevant part of IEC 60068 and also for diagnostic testing. The purpose of the shock test is to reveal mechanical weakness and/or degradation in specified performance. It can also be used to determine the structural integrity of a test specimen or as a means of quality control.

Machines used for simulation of earthquakes, sonic booms, explosions and implosions, bursting tests, metalworking, forming, etc. are not covered in this International Standard.

Several techniques for generating the desired shock motion are discussed. Both simple-pulse and complex transients can be produced. The simulation of transients can be achieved by control of the test with a specified shock-response spectrum.

NOTE 1 Annex A gives a description of pulse-shaping devices. Annex B defines methods of application of the shock response spectra. Annex C considers a method of evaluating the possibility of using a vibration generator for producing a shock pulse. Annexes D and E deal with the methods of measurement of some characteristics in inspection methods (or procedures) of shock-testing machines.

NOTE 2 Characteristics of vibration-generating equipment are covered in ISO 5344, ISO 6070 and ISO 8626.

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.

ISO 2041:1990, *Vibration and shock — Vocabulary*

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 15261, *Vibration and shock generating systems — Vocabulary*

ISO 16063 (all parts), *Methods for the calibration of vibration and shock transducers*

IEC 60068-1:1988, *Environmental testing — Part 1: General and guidance*

IEC 60068-2-27:1987, *Environmental testing — Part 2: Tests — Test Ea and guidance: Shock*

IEC 60068-2-81, *Environmental testing — Part 2-81: Tests — Test Ei: Shock — Shock response spectrum synthesis*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 15261 and the following apply.

3.1
check point
fixing point nearest to the centre of the table surface of the shock-testing machine, unless there is a fixing point having a more rigid connection to the table, in which case the latter point is used

3.2
nominal load
maximum load used for the testing of a shock-testing machine as specified by the manufacturer

3.3
shock-testing machine
device for subjecting a system to controlled and reproducible mechanical shock

[ISO 2041:1990, 3.23]

NOTE Shock-testing machines can be classified as specially designed shock generators, gravity and powered, and vibration generators of electrodynamic and servo-hydraulic types used in a shock mode.

4 Performance

4.1 General

The performance of a shock-testing machine is based on a relatively slow accumulation of energy used to reproduce a shock, and its consequent discharge in an energy-transducing device for a short period of time.

The energy needed to create a shock may be achieved by the work against gravity (in free-fall machines) or, if the shock is in a direction other than upwards or if the free-fall machine does not provide enough velocity change, the necessary potential energy may be supplied by elastic cords, springs or hydraulic and pneumatic means.

The shock can also be achieved by releasing compressed gas, by explosives or by transfer of momentum from one moving mass to another.

4.2 Operation principles

According to the principle used, shock-testing machines are classified as free-fall or accelerated shock-testing machines, or as gas guns or explosive guns, hydraulic and pneumatic, as well as servo-hydraulic and electrodynamic.

The shock pulse (either a single-pulse or a transient vibration) is produced by a shock pulse-shaping device mounted on the table or carriage, on the reaction mass, or on both. A wide selection of pulse shapes can be produced depending on how the kinetic energy is transferred by pulse-shaping devices. Annex A gives some guidelines on the selection of pulse-shaping devices.

Pulse-shaping devices can be used in a rebounding or non-rebounding mode. Usually the device that attaches the test specimen is initially accelerated and a shock is produced during the rebound of the test specimen. Sometimes (for large masses or when the acceleration of the test specimen during shock pre-history is undesirable) a reaction mass or a hammer can be initially accelerated and the shock is produced as a result of the impact between the reaction mass and the device that attaches the test specimen. This mode is classified as non-rebounding.

As an alternative to the shaping of the shock pulse, for electrodynamic or servo-hydraulic vibration generators, a shock-response spectrum of the impulse to be applied to the specimen may be shaped to be similar to the required shock-response spectrum.

When the test specification requires some tolerance for a test shock-response spectrum (e.g. +3 dB, −1,5 dB), electrodynamic and servo-hydraulic test equipment for generating vibration may also be used for shock testing. These machines can generate classical shock waveforms (half-sine, trapezoidal, saw-tooth, etc.) as well as arbitrary waveforms which have the required shock-response spectra, and are usually produced by means of digital control, but generally have limited velocity and displacement capability. A method for maintaining the above limitations is briefly treated in Annex C. Characteristics of vibration-generating equipment are covered in ISO 5344, ISO 6070 and ISO 8626.

4.3 Test types

4.3.1 Shock pulse generation

Classical shock pulse shapes in accordance with IEC 60068-2-27 are generated with additional pre-pulse and post-pulse shaping to limit velocity and displacement. The amplitude of the pre-pulse and post-pulse shapes is limited to a small fraction of the primary pulse amplitude.

4.3.2 Shock-response spectrum generation

A brief, low-level oscillatory transient impulse is typically applied to the specimen. The shock-response spectrum is measured, compared with the desired shock-response spectrum, and the difference used to modify the shape of the next impulse. Typically, this process is repeated several times until the desired shock spectrum is achieved, and then an input transient impulse of the desired level is applied to the specimen. The desired shock spectrum may be either standardized (i.e. one of the shock spectra of Annex B) or the shock spectrum of a field environment.

4.4 Shock-testing machine components

A shock-testing machine consists of the following:

a) a rigid table or carriage with means of attaching test specimens and shock pulse-shaping devices;

b) a set of guides that controls the movement of the carriage;

c) a means for storing the potential energy necessary for imparting the shock, such as provisions for hoisting or preloading springs and cords attached to the carriage;

d) a means for securing the carriage at a selected drop height or position, prior to initiation of the shock pulse;

e) a release mechanism;

f) a reaction mass or base upon which the carriage impacts;

g) a pulse-shaping and rebound braking system, or means to generate and control the shock spectra;

h) control equipment;

i) shock-measuring system;

j) auxiliary power, cooling and other equipment, as required.

5 Shock-testing machine specification

The motion of the table or carriage may be specified by shock-response spectra and/or time-history parameters. Depending on the type of shock-testing machine (specially designed shock generators or vibration generators used in a shock mode), where applicable, data together with tolerances, shall be given for the following items:

a) available pulse shapes for free fall and accelerated tables;

b) maximum velocity change;

c) maximum displacement;

d) range of reproducible shock-pulse peak accelerations versus pulse durations;

e) initial or pre-pulse acceleration and final or post-pulse acceleration;

f) minimum shock-pulse duration;

g) frequency range of wavelets to reproduce a shock-response spectrum;

h) shock-response spectrum flatness with resolution in 1/3, 1/6 or 1/12 octave;

i) maximum drop height, preload pressure or charge;

j) tare mass of table or carriage and total moving mass;

k) maximum allowable axial force of specimen-mounting screw;

l) natural frequencies of the table or carriage;

m) natural frequencies of the machine on its foundation;

n) required pressure and volume of gas and liquids;

o) quantities and flow rates of fluid or gas for the operation of the machine;

p) type of rebound braking system and braking force;

q) size and overall dimensions of the machine and its parts, especially the table or carriage and its accessories;

r) dimensions, mass and mounting method of reaction masses and floor-loading requirements;

s) maximum size and mass of test specimen;

t) mounting facilities for test specimen and transducers;

u) number of shocks (shock pulses) possible per unit time, or, alternatively, minimum period between two shocks;

v) specification of the shock-measuring system employed;

w) centre of gravity of the table, plus the effect of any off-centre load;

x) acceptable range of environmental conditions, i.e. temperature, humidity, etc.

6 Requirements for shock-testing machines

6.1 General

The performance of shock-testing machines shall be defined and specified by the manufacturer.

Detailed installation, operation and maintenance instruction manuals shall be provided by the manufacturer.

Instructions shall include requirements for periodic inspection, maintenance and lubrication of the equipment. Signs of wear of replaceable components and possible structural failure shall be described by the manufacturer. Appropriate steps shall be proposed for replacing deteriorating pulse-shaping devices and for repairing leaks in the pneumatic and hydraulic systems.

Application and mounting of test specimens, adapter plates and fixtures to the table or carriage shall be thoroughly described. The effects on the test of eccentric or faulty loading of the carriage shall be explained.

Installation dimensions shall include adequate working room, overhead clearances and walk-ways around the equipment.

Electrical power requirements shall be stated and the normal operation of the machine shall not cause any interference in the power network that might affect the test monitoring instrumentation.

If a shock-testing machine operates by means of compressed gases or fluids, then adequate seals shall be used to prevent blow-out of gases or fluids during the test. All sections of barrels, cylinders and piping shall be designed with an adequate safety factor. The maximum expected pressures produced throughout the worst-case test should be considered.

6.2 Safety requirements

The overall machine design and installation shall provide sufficient safety and shall protect personnel from flying objects if the equipment or test specimen fails structurally.

Guns shall be located in restricted remote areas, with adequate blast-proof enclosures for the protection of personnel. Maximum gas pressures external to the gun and sound pressure levels shall be specified.

The table or carriage, piston or sabot shall be securely retained and fixed when being made ready for testing. The table or carriage shall be prevented from striking the reaction mass while personnel are assembling pulse-shaping devices.

Release or firing shall be possible only on command. The release mechanism shall be fail-safe and impossible to activate accidentally, for example by providing two simultaneously activated switches, one of which is lockable.

Gases that are likely to be compressed during testing shall not present any risk of spontaneous combustion by self-ignition.

It should be remembered that shock-testing machines can be used for human exposure testing and should therefore have proven reliability and safety. For such machines, the table or carriage shall be accessible immediately after the impact so that the human subject can be released quickly.

Protection shall be provided to protect human subjects from electrical terminals. The complete system shall meet appropriate safety requirements.

6.3 Table or carriage

The table of a vibration generator or the carriage of a shock generator (piston, sabot, spigot or tubes) and all accessories used for movement of the test specimen during the shock test shall be designed for maximum stiffness, strength and damping.

The means of attaching a test specimen and the limits of torque to be applied to the fixing screws shall be indicated.

In the case of test tables, it shall be stated whether or not they are fitted with replaceable threaded inserts, and whether they are recessed or raised. All test specimen mounting surfaces shall be geometrically flat and of minimum roughness and the applicable tolerances shall be stated. If the surface is fitted with recessed inserts, the flatness of the whole surface shall be indicated for normal reference atmospheric conditions (see IEC 60068-1:1988, Clause 5). If replaceable raised inserts are provided, the resulting co-planarity of the insert surfaces shall be given, based on the thickness tolerance of the insert flanges and the flatness of the insert-mounting surface.

The maximum torque to be applied to replaceable inserts during installation shall be stated, together with the types of materials being mated.

A drawing or diagram shall be provided giving all dimensions of the table or carriage, the dimensions and positional tolerances of the inserts, and the material from which they are made.

The maximum permissible torque and axial force that may be applied to the inserts shall be stated, together with the required perpendicularity of the test specimen fixing screws with respect to the mounting surface.

6.4 Hoisting or pre-loading

The free-fall and the accelerated shock-testing machines, and machines that use a hammer or a pendulum, shall be supplied with mechanisms for hoisting and pre-loading the carriage to a predetermined drop height or tension, for example by means of a built-in height- or angle-measuring scale with a residual indicator. The precision of the drop height or pre-load setting shall be specified, together with tolerances. The machine shall be fitted with devices to stop the carriage automatically or to indicate to the operator when the carriage has reached a predetermined drop height or pre-load. The manufacturer shall specify the maximum drop height or pre-load.

If the test has to be aborted, it shall be possible to disarm the machine and safely lower the table or carriage.

6.5 Braking systems

Shock-testing machines should be equipped with adequate braking systems. Braking may be achieved by mechanical, electrical, pneumatic or hydraulic devices. Shock-absorbing materials or parachutes may be employed on devices that are in free trajectory and these shall be recovered with minimum damage.

The design of the braking system shall ensure that minimum vibration is superimposed on the pulse trace and that shock tests can be limited to a single pulse.

Acceleration limits for braking shall be given by the manufacturer, together with information on the braking force required for controlled braking. The magnitude of acceleration applied during braking shall not exceed 25 % of that applied during the test pulse.

A shock-testing machine not equipped with a braking system should be adequately marked and shall be prevented by other means from causing damage.

6.6 Reaction mass

If a reaction mass is used, it shall be a large and rigid structure compared to the table or carriage.

The resonance of the reaction mass shall have sufficiently high frequencies to avoid distortion of the shortest shock pulse duration for which the machine is rated.

Seismically suspended reaction masses may be used. They may be installed when the shock has to be isolated from the surroundings and where reduced dynamic floor loading is required. They may also be used to control the recoil motion of the shock table or carriage by momentum transfer to the reaction mass.

The manufacturer shall provide or recommend the dimensions, masses and the ratio between the moving masses, including the test specimen and the reaction mass, together with mounting methods.

6.7 Shock pulse-shaping devices and methods

The springs, impact pads and pulse programmers or generators used for controlling the shock pulse (i.e. the pulse shape, duration and acceleration) depend on the dynamic force-deflection characteristics of the pulse-shaping device.

If two or more masses are involved in a momentum exchange, the shock motion of each mass shall be taken into consideration in the design of the shock pulse-shaping device.

Any special equipment needed to form the pulse-shaping devices (e.g. moulds for making lead forms) shall also be specified. Guidelines for choosing shock-shaping devices are given in Annex A

Similarly, a special electronic shock synthesizing controller typically is used to generate the input signal to an electrodynamic or servo-hydraulic vibration generator used to generate a shock impulse (see Annex B).

7 Inspection of a shock-testing machine

7.1 General

A procedure shall be specified for performing a shock inspection test for periodic evaluation of system performance. A periodic inspection of the test equipment characteristics shall be carried out in accordance with the specified control method or manual.

The inspection interval for a shock-testing machine should be recommended by the manufacturer, and may be changed by the user depending on the constancy of the characteristics to be certified and the use of the shock-testing machine with respect to time.

7.2 Preparation procedure

The shock-testing machine shall be supplied with at least two equivalent loads of m_{nom} and 0,5 m_{nom}, where m_{nom} is the mass of the nominal load. If the shock-testing machine is used for testing specimens whose mass (including the mass of the means for attaching a test specimen) is less then 0,1 m_{nom}, calibration may be done with zero load. A monolithic metal cylinder or prism with the ratio of height to diameter from 0,2 to 1,0 is recommended as an equivalent load. (For electrodynamic vibration generators used in a shock mode, see ISO 5344.)

NOTE It is possible to use models, adapter plates and attachment fixtures as equivalent load test specimens. In this case, the results of the calibration of the shock-testing machine are valid only for the mentioned test specimens.

The design of an equivalent load shall enable mounting of an accelerometer at the check point of the table or carriage. Generally, check point coordinates coincide with the geometrical centre of the table or carriage surface if there are no other instructions provided by the manufacturer.

Shock-measuring instruments used for the calibration of the shock-testing machine shall provide measurements in the range of the shock accelerations and pulse durations corresponding to the range of the shock-testing machine. The total uncertainty of the shock-measuring instruments, including amplitude nonlinearity of the transducer and dynamic errors of the transducer and amplifier, shall provide the true value of the shock process as measured in the intended direction at the check point to be within the tolerances required by IEC 60068-2-27 and IEC 60068-2-81, or within the tolerances specified by the manufacturer.

For a tolerance value equal to 20 %, the total uncertainty related to shock-measuring instruments shall not exceed 7 % at a confidence level of 95 %. Calibration of the shock-measuring instruments shall be carried out in accordance with the corresponding part of ISO 5347 or ISO 16063.

The accelerometer shall be mounted on the table in accordance with ISO 5348. In order to reduce the error of shock measurements due to the strain of the table or carriage of the shock-testing machine, and if a transverse shock motion has to be measured, an additional cube or cylinder may be used. In such cases, the accelerometer shall be mounted on a steel cube or cylinder, whose maximum size shall not exceed 30 mm.

The user of the shock-testing machine shall specify the desired inspection items and conditions (e.g. the exact values of load equivalents, peak accelerations and pulse durations, and/or the desired shock-response spectrum.

7.3 Example of an inspection procedure for a shock-testing machine operation

7.3.1 Preliminary inspection

During preliminary inspection, the following items should be checked:

- the presence of the operating manual for the shock-testing machine;
- installation of the shock-testing machine in accordance with the manufacturer's specifications;
- the presence and validity of verification of shock-measuring instruments specified for the shock-testing machine;
- shock-test mode settings;
- shock-measuring system function;
- compliance with the safety requirements in the manufacturer's documents.

7.3.2 Periodic inspection

For each test operating mode of a shock-testing machine, inspection should be made of the following shock parameters (where applicable).

7.3.2.1 Range of peak accelerations

Measurements should be made for minimum, maximum and medium values of peak accelerations reproduced by a shock-testing machine with no load and with nominal load mass. At least three shocks for each test mode are recommended. The mean value of several readings for peak acceleration, pulse duration for each shock-test mode, and each fixed load equivalent should be evaluated.

7.3.2.2 Range of shock-pulse durations

The pulse duration should be determined for the averaged acceleration curve at a specified acceleration level (typically at 10 % of the peak acceleration value).

7.3.2.3 Available pulse shapes

Classification of a shock pulse should be done by comparing the averaged acceleration curve with the shock pulses and tolerances according to IEC 60068-2-27, if the other specific tolerances are not stated in the test standards.

7.3.2.4 Ratio of superimposed oscillations in the time history of shock acceleration

If there are transient oscillations in the shock acceleration curve with a span that does not exceed 20 % of the averaged value, the peak value on the averaged acceleration curve is taken as the peak acceleration. If the span of superimposed oscillations in the time history of the shock acceleration curve exceeds 20 % of an averaged value, the ratio of superimposed oscillations should be stated in accordance with Annex B.

7.3.2.5 Instability of peak accelerations or repeatability of shock-response spectrum for shock-testing machines for repeated shocks, as well as for shock-testing machines which do not have a built-in measuring system

For shock-testing machines for repeated shocks, as well as for shock-testing machines without built-in shock-measuring systems, the instability of the peak acceleration or the repeatability of the shock-response spectrum should be determined. For shock-testing machines that generate single shocks, the maximum deviation of peak acceleration from the averaged value in a series of several shocks for a specified shock-testing mode is defined as instability. For shock-testing machines for repeated shocks, the initial and the final values of the averaged peak acceleration for the specified shock-testing mode should be used.

7.3.2.6 Number of shocks (shock pulses) possible per unit time for shock-testing machines for repeated shocks (where applicable)

The number of shocks per unit time should be determined for shock-testing machines for repeated shocks as an average number of shocks per minute for a specified shock-testing mode.

7.3.2.7 Uniformity of shock acceleration across the table or carriage

The uniformity of the shock acceleration within the table or carriage should be determined by means of two shock-measuring channels. A method should be used in accordance with Annex D. One accelerometer should be mounted at a check point on the table or carriage and the other at the most distant point from the first one. The measurements should be carried out without a test load to achieve the maximum shock acceleration that can be reproduced by the shock-testing machine.

7.3.2.8 Relative transverse shock acceleration reproduced by a shock-testing machine

Measurement of the relative transverse shock acceleration reproduced by a shock-testing machine should be done by means of a triaxial shock accelerometer mounted at a check point on the table or carriage. Three one-axial accelerometers mounted on a steel cube may be used. The relative transverse sensitivity of the accelerometers should not exceed 5 %. The lowest mounted resonance frequency of the accelerometers and their upper shock limit in the transverse direction should enable measurement of transverse shock accelerations. The uncertainty of these measurements should not exceed three times the uncertainty of measurements in the main direction. The average value of the peak acceleration reproduced by a shock-testing machine with one-half of the nominal load should be chosen by the manufacturer. The method of calculation of the relative transverse shock acceleration is described in Annex D.

7.3.2.9 Stray magnetic field over the table of an electrodynamic shock-testing machine

The maximum value of the stray magnetic induction over the table of an electrodynamic shock-testing machine should be measured (see Annex E). It may be measured once during initial inspection.

7.3.2.10 Shock-response spectrum for those test-operating modes that are declared by the manufacturer

The shock-response spectrum should be determined in accordance with Annex B for those shock-testing modes that do not correspond to IEC 60068-2-27 pulses. The produced shock spectrum should be in agreement with test standards or with the manufacturer’s specification.

Annex A
(informative)

Devices for shaping various pulse shapes

A.1 Devices for shaping half-sine and triangular pulses

A.1.1 General

The half-sine and triangular shock-pulse shapes are usually generated by various rebounding devices. The combination of the impacting mass and the pulse-shaping device then simulates the classic undamped one-degree-of-freedom spring-mass system, and the shock pulse is one-half cycle of the oscillation of this system. The shock pulse-shaping device acts as the spring. A perfectly linear or quasi-linear spring (linear force versus deflection) will generate a half-sine pulse. Progressively greater non-linear stiffening spring characteristics will generate cusp pulses approximating triangular shapes.

A.1.2 Elastomer pulse-shaping devices

Elastomers are quasi-elastic pulse-shaping devices and are normally used to generate half-sine pulses where high spring rates are required; triangular or parabolic cusps result as the material is more strained. Materials include rubber and rubber-like plastics and are generally re-usable for many shock pulses.

A.1.3 High-strength plastics

High-strength plastic materials are quasi-elastic pulse-shaping devices normally used to generate short-duration half-sines where a high-dynamic spring rate is required. Many high-strength plastics may be used (e.g. polypropylene, vinylidene chloride, acetyl homopolymer resins and fibre-laminated phenolics). Normally, the pulse-shaping device is designed with a maximum stress within the elastic limits, allowing multiple re-use. Triangular pulses can be generated when these materials are compressed in series with the materials offering an appropriate linear stiffness.

A.1.4 Liquid and quasi-liquid springs

A liquid spring is a quasi-elastic pulse-shaping device that is normally used to generate half-sine pulses. A liquid spring is a hydraulic cylinder in which a liquid (e.g. hydraulic oil) is compressed during pulse generation. Variation in design configuration can permit spring-rate variations for changes in pulse duration and peak acceleration. The spring may be re-used without recharging. Quasi-liquid springs contain pliable elastomers that operate like a liquid spring.

A.1.5 Gas spring (variable force)

A gas spring is an elastic, pulse-shaping device that may be used to produce an adjustably shaped, symmetrical pulse depending upon the initial preload pressure in the spring, the initial volume, and the change in volume during the shock. Generally, a low preload pressure and a great decrease in volume (with respect to the initial volume) will produce a cusp pulse. Nitrogen is normally used.

A.2 Devices for shaping rectangular and trapezoidal pulses

A.2.1 General

Rectangular and trapezoidal pulses require a pulse-shaping device that exerts a constant force with time (and deflection). Such a device can behave inelastically or elastically.

A.2.2 Moulded lead forms

Lead moulded into pellet form and different types of lead blocks may be used to make crushable rectangular pulse-shaping devices. These devices are limited to shorter stroke pulses. The lead pellet or block is replaced after each test; however, the lead may be melted and remoulded.

A.2.3 Honeycomb

Honeycomb is an inelastic, pulse-shaping device that can be produced with metallic or fibrous materials made into thin-walled cells that buckle and permanently deform during loading. It can be shaped to produce controlled-rise-time, trapezoidal pulses. The honeycomb is replaced after each test.

A.2.4 Gas spring (quasi-constant force)

Gas springs are often used to generate rectangular or trapezoidal pulse shapes. The spring usually has a high precharge pressure and small volume change (with respect to initial volume), which produces a quasi-constant force during the spring deflection. When used in series with elastomers or liquid springs, this spring generates trapezoidal pulses.

A.3 Devices for shaping peak sawtooth pulses

A.3.1 General

The pulse-shaping device for peak sawtooth pulses should have a linear stiffening compression spring rate. The pulse-shaping device for the final-peak sawtooth pulse should have a non-linear stiffening compression spring rate. The force output decays rapidly to zero when it reaches its peak value. Because of their asymmetry, these pulses are always generated with non-rebounding devices.

A.3.2 Moulded lead forms

Moulded lead is a relatively inelastic deformation-type pulse-shaping device. The shape of the lead determines the shock-pulse shape. For example, crushing a conical form generates a terminal-peak shock pulse approximating a sawtooth. The form can be used only once, since its shape is destroyed during the shock pulse. However, the lead may be melted and remoulded.

A.3.3 Shaped honeycomb

Different configurations of honeycomb (see A.2.3) may be used to generate non-symmetrical pulse shapes, for example a sawtooth pulse shape is generated if the honeycomb is a triangular prism shape where the cross-sectional area of contact increases linearly with deformation.

A.3.4 Precharged differential-area gas cylinders

Precharged differential-area gas cylinders used in series with quasi-elastic materials can provide the combination of a constant or stiffening-spring-rate device and a rapid-force-decay device. The rise-time portion of the pulse is controlled by the quasi-elastic materials. The maximum amplitude and fall time are controlled by the gas cylinder.

Annex B
(informative)

Shock-response spectra, shock synthesis and analysis

B.1 Introduction

IEC 60068-2-27 specifies one of three pulse shapes (the final-peak sawtooth pulse, the half-sine pulse and the trapezoidal pulse), with a stated severity, to be applied to the specimen fixing points and does not restrict the testing to specific machines. The choice of pulse shape and severity should be made in accordance with technical considerations appropriate to the project or type of specimen.

Methods involving shock-response spectra should be regarded as acceptable from the standpoint of reproducing the effects of actual shock environments. In order to obtain tests which are both reproducible and which can be related to practical application, the basic concepts of shock-response spectrum use should be taken into consideration in producing the test procedure for the shock test. The concepts involved are given in Appendix B of IEC 60068-2-27:1987.

B.2 Shock synthesis

Many shock-induced motions observed in service have waveforms that are predominantly oscillatory in character. A specified shock-response spectrum can be produced by a variety of shock pulse shapes. The shock-response spectrum does not uniquely specify the shock pulse shape, primarily because the shock-response spectrum does not define the time history of the shock pulse components.

A suitable time history may be synthesized in several ways, for example, as a sum of decaying wavelets:

$$a(t) = \sum_i A_i \exp(-\varepsilon_i \omega_i t) \sin(\omega_i t + \varphi_i) \qquad \text{(B.1)}$$

where

$a(t)$ is the time history of shock acceleration;

A_i is the amplitude of the i th wavelet;

ε_i is the relative damping factor of the i th wavelet;

ω_i is the angular frequency of the i th wavelet;

φ_i is the initial phase of the i th wavelet.

The values of A_i, φ_i and ε_i typically have some random distribution within their ranges for repeated shocks for the same shock-testing machine.

In practice, a shock-testing machine can be realised using an electrodynamic or servo-hydraulic vibration generator connected to digital control equipment. The control equipment calculates the required acceleration time history to be generated on the table of the vibration generator by the following procedure:

a) provide a bank of parallel single-degree-of-freedom oscillators with defined natural frequency intervals and damping factors;

b) generate a time history by summing up a large number of wavelets with different frequencies ω_i [see Equation (B.1)];

c) input the time history to the bank of parallel single-degree-of-freedom oscillators;

d) measure the maximum response value of each oscillator; the plot of these values as a function of natural frequencies is the shock-response spectrum of the time history generated in procedure b);

e) compare the shock-response spectrum to the required one and calculate the difference at each natural frequency;

f) generate a new time history, which satisfies the required shock-response spectrum, using the difference. Then repeat procedures c) to f) until satisfactory coincidence is achieved.

The resultant time history will be the required acceleration time history on the table. Then begin the equalization procedure using the time history as a reference waveform. The transfer function of the vibration generator, including a test specimen and a fixture, should be used for equalization.

NOTE 1 The calculation and equalization procedures are sometimes joined together.

NOTE 2 See also IEC 60068-2-81.

The maximum response values of oscillators do not represent the highest acceleration in the time history on the table of the vibration generator. The high-frequency asymptotic value of the shock-response spectrum should be taken as the highest acceleration in the time history, and is called the zero-period acceleration of the required shock-response spectrum.

The input impulse waveforms provided by these more sophisticated shock controllers typically allow a specific vibration generator to generate output shock spectra many times as large as the output shock spectra which would result from an input signal similar to the shape of the classical shock pulse. Actually, to produce a specified shock response in a specimen by means of a synthesized shock, a considerably lower input force is required than when using a conventional shock-testing machine. This is because the specimen is subjected to an oscillatory transient, rather than to a single pulse.

B.3 Shock analysis

For effective calculation of the initial shock-response spectrum, the following procedure based on the discrete analogue of the second-order differential equation may be used [8]:

$$y_m = b_0 x_m + b_1 x_{m-1} + b_2 x_{m-2} - c_1 y_{m-1} - c_2 y_{m-2} \tag{B.2}$$

where

y_m, y_{m-1}, y_{m-2} are the single-degree-of-freedom system response acceleration time series (instantaneous values spaced at the quantizing interval T_d);

x_m, x_{m-1}, x_{m-2} are the input acceleration time series [a sample of the specified exciting shock $a(t)$];

b_0, b_1, b_2, c_1, c_2 are the coefficients of the discrete analog of the Z transfer function of the single-degree-of-freedom system, given by the following formulae:

$$b_0 = 1 - E\frac{\sin K}{K} \tag{B.3}$$

$$b_1 = 2E\left(\frac{\sin K}{K} - \cos K\right) \tag{B.4}$$

$$b_2 = E\left(E - \frac{\sin K}{K}\right) \tag{B.5}$$

$$c_1 = -2E\cos K \tag{B.6}$$

$$c_2 = E^2 \tag{B.7}$$

where E and K are the auxiliary coefficients given by the following formulae:

$$E = \exp\left(-2\varepsilon\pi f_n T_\mathrm{d}\right) \tag{B.8}$$

$$K = -2\varepsilon\pi f_n T_\mathrm{d}\sqrt{1-\varepsilon^2} \tag{B.9}$$

and where

f_n is the undamped natural frequency of a single-degree-of-freedom system;

ε is the damping ratio;

T_d is the quantizing interval.

The accuracy and robustness of the solution are achieved by limiting the value of f_n to five discrete values in a period of oscillations. If the damping ratio is not zero, then for a sufficiently long block response length, the overall shock-response spectrum can be achieved.

If the damping of the system is negligible, then the maximum response of the system to a complex shock is usually achieved during the after-effect. In this case, the most effective way of calculating the residual shock-response spectrum is by Fast Fourier Transform of the exciting shock process and then successive multiplying of the Fourier coefficients of the values of the angular frequencies.

The shock spectra calculation algorithms should be certified by means of test signals with known theoretical solutions for response. The maximum errors can be achieved for a rectangular pulse input, which should be used as a test signal.

For shock-testing machines producing complex shocks with random amplitudes and phases at certain frequencies, the average of several ensembles should be used. Smoothing of the calculated result is also recommended. If the share of high-frequency components is large, it is preferable to present the results on a logarithmic scale.

The ratio of superimposed oscillations is one of the important characteristics of the shock produced by the shock-testing machine. This ratio should be rated and checked during the inspection procedures. To calculate the ratio of superimposed oscillations using the time history of the shock acceleration, the following formula may be used:

$$r_\mathrm{so} = \frac{1}{2\cdot A_\mathrm{p}}\cdot\sum_{i=1}^{n+1}\left|\left(A_i - A_{i-1}\right)\right| \tag{B.10}$$

where

r_so is the ratio of superimposed oscillations;

A_p is the peak value of the smoothed acceleration;

A_i is the maximum (odd i) or minimum (even i) in the time history of the shock acceleration;

n is the number of extreme points in the time history of the shock acceleration.

Annex C
(informative)

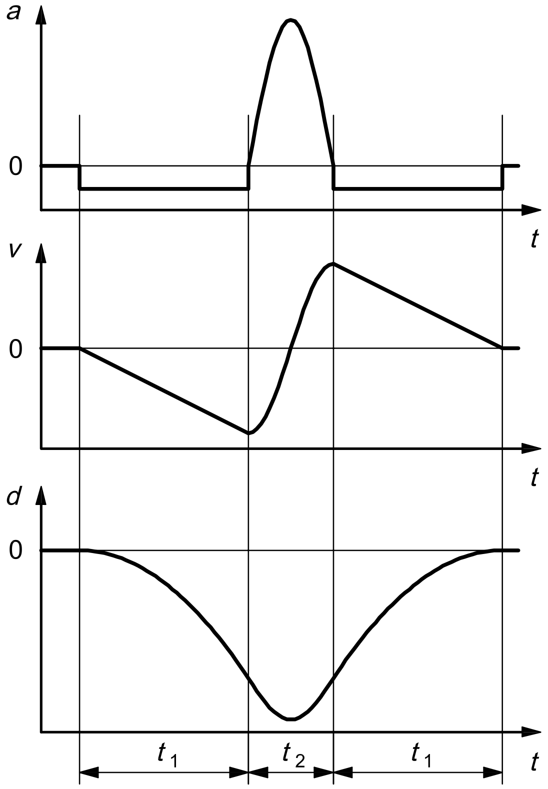
Use of a vibration generator for producing a shock pulse

Particular acceleration/time waveforms can be produced by an electrodynamic vibrator to produce repeated shocks. Various classical waveforms (such as half-sine, sawtooth, trapezoidal, etc.) can be accurately and repeatedly simulated using computer-based controllers.

In order to obtain a half-sine acceleration waveform at the test load, the vibrator must be controlled in such a way that the usual ratings of force, acceleration, velocity and displacement are not exceeded.

The main problem occurs in producing the satisfactory pre-pulse and post-pulse acceleration waveforms which are used to position the vibrator armature to provide the best possible acceleration waveform.

If, for simplicity, a theoretical acceleration waveform is assumed to be half-sine with rectangular pre- and post-pulses (see Figure C.1), then the maximum allowable peak acceleration A_p for a given displacement range R varies with the relative reverse acceleration, which typically does not exceed 20 %.



a is the shock acceleration
v is the shock vibration
d is the shock displacement
t is the time

Figure C.1 — Acceleration, velocity and displacement time-histories for a half-sine pulse with rectangular conditioning

If a body of the vibrator has a mass M_b and the armature plus load has a mass M_a, a derating must be applied to the peak acceleration A_p to take account of the motion of the vibrator body which moves in the opposite direction to the armature.

Additionally, account should be taken of the maximum force rating and velocity for a given system. In general, a force rating of up to twice the sine rating can be used, provided that it is within the rating of the vibration system.

The velocity change limit is set by the maximum output voltage available from the power amplifier which drives the vibrator, and which depends on the design of the vibrator and the power amplifier.

The following relationships are valid for a half-sine pulse with rectangular pre- and post-pulses:

$$\Delta v = \frac{2A_p \cdot t_2}{\pi} \tag{C.1}$$

$$A_p = \frac{2\pi^2 R \cdot P}{{t_2}^2 (1+2P)} \times \frac{m_b}{m_b + m_a} \tag{C.2}$$

where

Δv is the velocity change due to the shock;

A_p is the peak acceleration;

t_2 is the pulse duration;

R is the displacement range;

P is the ratio of the relative reverse acceleration to the peak acceleration;

m_b is the mass of the body of the vibrator;

m_a is the sum of the mass of the armature and load.

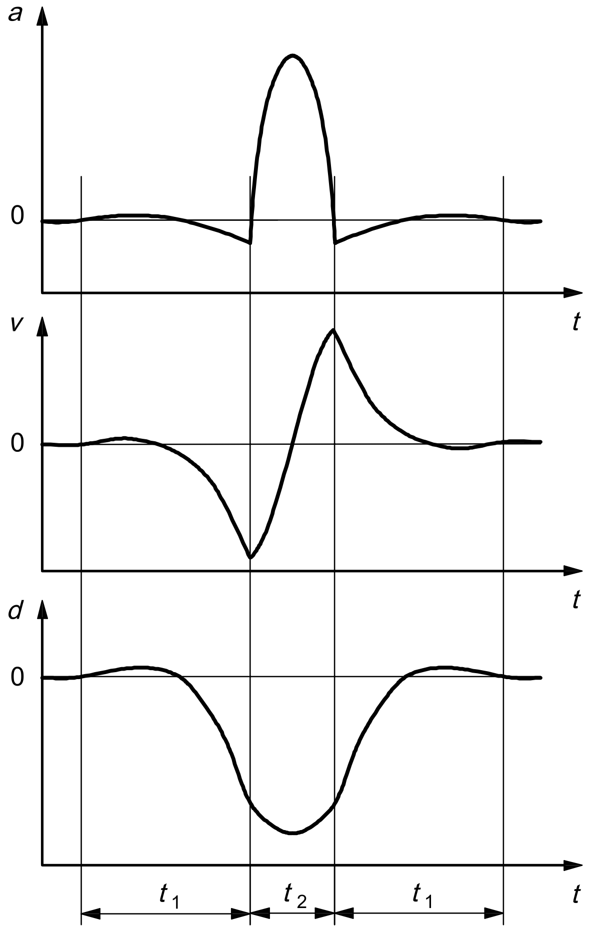
The data in Table C.1 have been prepared in accordance with Equations (C.1) and (C.2), assuming that a vibrator has a 51 mm (2,0 in) peak-to-peak displacement range and a fraction of reverse acceleration P equal to 0,1.

Table C.1 gives typical values of peak acceleration A_p expressed as g_n (g_n is the standard acceleration of free fall, equal to 9,806 m/s^2) and pulse duration t_2, in milliseconds, for a 10 % negative acceleration (P = 0,1).

These relationships should be used for general guidance only, because the pre- and post-pulses are not usually rectangular (see Figure C.2). This will make a small difference to the calculated values.

Table C.1

A_p g_n	t_2 ms
5	30
10	16
15	11
25	6
30	11
40	11
50	11
75	11



a is the shock acceleration
v is the shock vibration
d is the shock displacement
t is the time

Figure C.2 — Acceleration, velocity and displacement time-histories for a half-sine pulse with optimized conditioning

To analyse the dynamic response of a vibration-generating machine for an arbitrary shock input signal, the following method of obtaining its transfer function is recommended.

a) Substitute a sine input signal *u* applied to the amplifier of the vibration-generating machine with a rectangular one of the same peak value of input voltage.

b) Acquire a response signal *a* of the vibration-generating machine with respect to time and adjust the period and amplitude of the input signal to provide a response signal without clipping and full-time reaction of the vibration-generating machine (see Figure C.3).

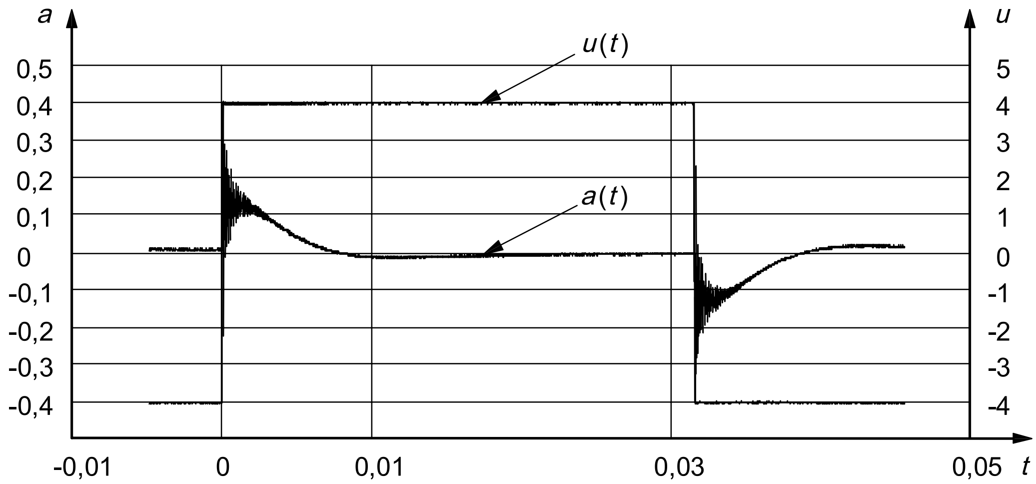
c) Acquire and analyse the low-frequency response of the vibration-generating machine with respect to time (see Figure C.4).

d) Acquire and analyse the middle-frequency response of the vibration-generating machine with respect to time (see Figure C.5).

e) Acquire and analyse the high-frequency response of the vibration-generating machine with respect to time (see Figure C.6).

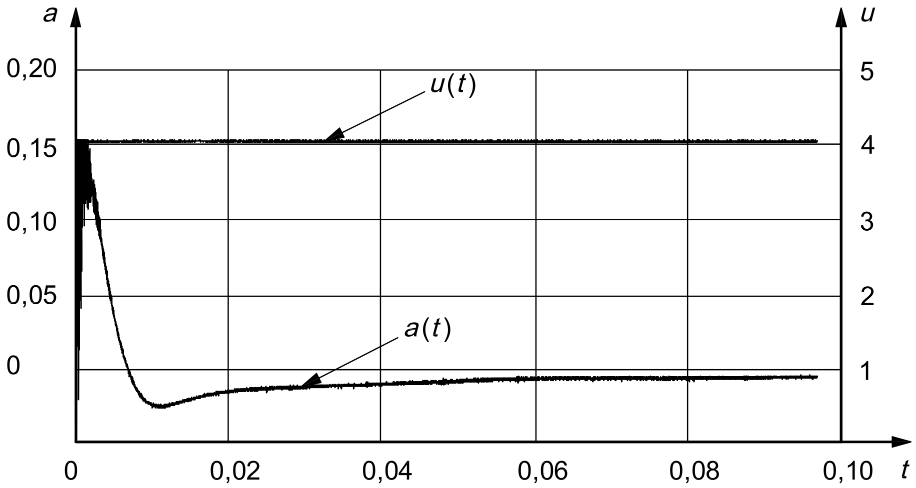
f) Use the obtained data to get an approximate relative transfer or impulse transfer function of the vibration-generating machine.

g) Calculate the response of the vibration generator for any arbitrary shock input signal as its convolution with the obtained impulse transfer function.



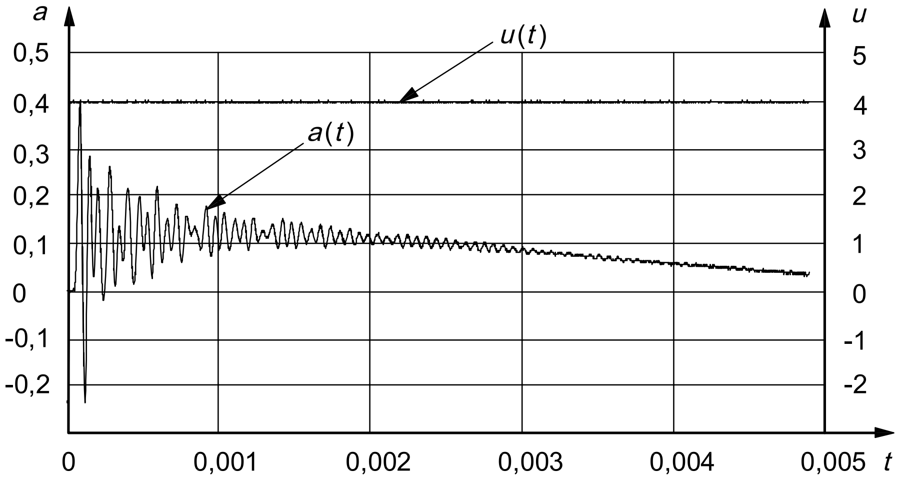
a is the output acceleration
u is the input voltage
t is the times, in seconds.

Figure C.3 — Adjusted input signal for obtaining a transfer function of a vibration-generation machine with respect to time



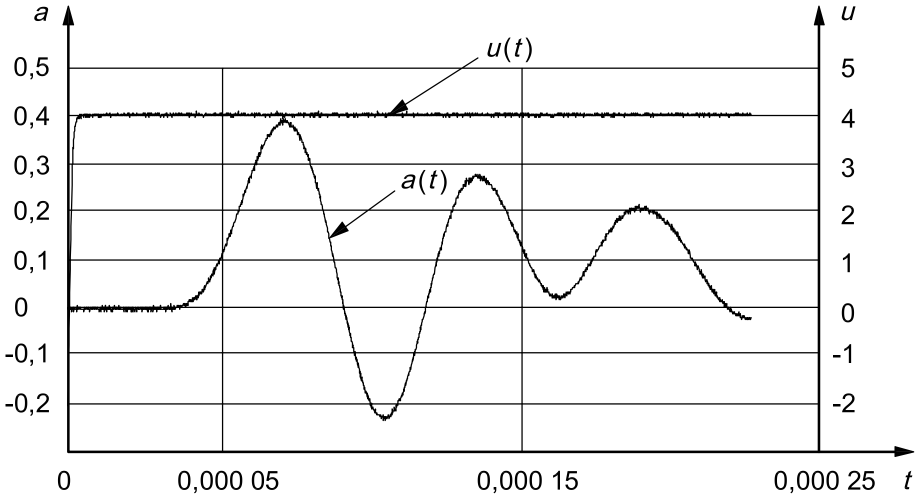
a is the output acceleration
u is the input voltage
t is the time, in seconds

Figure C.4 — Low-frequency response of a vibration-generating machine with respect to time



a is the output acceleration
u is the input voltage
t is the time, in seconds

Figure C.5 — Middle-frequency response of a vibration-generating machine with respect to time



a is the output acceleration
u is the input voltage
t is the time, in seconds

Figure C.6 — High-frequency response of a vibration-generating machine with respect to time

Annex D
(normative)

Determination of uniformity of acceleration and relative transverse motion on the table of a shock-testing machine

D.1 Determination of uniformity of acceleration on the table of a shock-testing machine

Measure the uniformity of acceleration on the table of a shock-testing machine by means of a substitution method. One accelerometer shall be mounted at a check point on the table or carriage, and the other at the most distant point from the first one.

Initially, measure the mean value of the ratio of peak signals of a pair of accelerometers (A and B) for reference shock accelerations and pulse durations $(U_{P\mathrm{A}}/U_{P\mathrm{B}})_1$.

Then interchange the accelerometers between the same mounting points on the table of the shock-testing machine (substitute each other). Measure a new mean value of the ratio of peak signals of the same accelerometers $(U_{P\mathrm{A}}/U_{P\mathrm{B}})_2$.

Evaluate the uniformity of acceleration on the table of the shock-testing machine relative to the check point on the table, using the following formula:

$$K_{\mathrm{un}} = \sqrt{\frac{(U_{P\mathrm{A}}/U_{P\mathrm{B}})_1}{(U_{P\mathrm{A}}/U_{P\mathrm{B}})_2}} \times 100\ \% \qquad \text{(D.1)}$$

where

K_{un} is the relative uniformity of acceleration on the table of the shock-testing machine (%);

$(U_{P\mathrm{A}}/U_{P\mathrm{B}})$ is the mean value of the ratio of peak signals of accelerometers A and B mounted in the first and in the second cases.

D.2 Determination of relative transverse motion on the table of a shock-testing machine

Evaluate the relative transverse motion on the table of a shock-testing machine using the following formula:

$$K_{\mathrm{tr}} = \max\left\{\frac{\sqrt{a_{xi}^2 + a_{yi}^2}}{a_{zi}}\right\} \times 100\ \% \qquad \text{(D.2)}$$

where

K_{tr} is the relative transverse motion (%);

a_{zi} is an element of the array of shock accelerations in the direction of the line of shock (m/s^2);

a_{xi}, a_{yi} are elements of the array of shock accelerations in the direction transverse to the line of shock (m/s^2).

Accelerations a_{xi}, a_{yi}, a_{zi} shall be measured at the same moment of time during the shock pulse. The value giving a maximum K_{tr} shall be chosen.

If a cube for mounting one-axial accelerometers is used, the following condition shall be checked:

$$\frac{c}{4L} \geqslant \frac{5}{t} \tag{D.3}$$

where

c is the acoustic velocity in the material of the cube (m/s);

L is the length of the edge of the cube (m);

t is the shortest pulse duration (s).

Annex E
(normative)

Stray magnetic field

The manufacturer shall state the stray magnetic field with the test table in the unloaded condition. Along the axis, it shall be specified as a function of the distance from the centre. Over the surface, it shall be specified directly above each of the threaded inserts at a distance from the surface of the test table of one-quarter of the largest bolt circle diameter. The value given shall be the maximum value of the magnetic field in the area of the point under consideration.

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