INTERNATIONAL STANDARD

ISO 9688

First edition
1990-12-15

Mechanical vibration and shock — Analytical methods of assessing shock resistance of mechanical systems — Information exchange between suppliers and users of analyses

Vibrations et chocs mécaniques — Méthodes analytiques de l'évaluation de la résistance aux chocs des systèmes mécaniques — Échange d'informations entre les fournisseurs et les utilisateurs d'analyses

Reference number
ISO 9688:1990(E)

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.

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.

International Standard ISO 9688 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock*.

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

Introduction

This International Standard specifies the elements of the essential technical dialogue that must be established between a customer (who needs an analytical assessment of shock resistance) and the supplier (the person carrying out the analysis). It is intended to be a guide on what information should be exchanged between a customer and a supplier of an assessment of the shock resistance of a mechanical system (a product or human subject) where the assessment is based on computational analysis.

Normally, and where practicable, the shock resistance of the equipment or structural components should be verified by shock tests. Test procedures and test performance are already covered in some fields by International Standards, such as

IEC 68-2-27:1987, *Environmental testing — Part 2: Tests — Test Ea and Guidance: Shock*.

ISO 8568:1989, *Mechanical shock — Testing machines — Characteristics and performance*.

Through hands-on experience, a shock test can provide engineers with insight into the mechanical response of a machine, vehicle, structure or human subject to which an impact load has been applied. Such tests enable an engineer to determine the mechanical and functional reliability of a product and of a human subject more accurately than by computation. A product subjected to a physical test to assess its resistance to shock usually shows greater resistance than is indicated by an assessment of its resistance based on a mathematical analysis. However, there is an increasing reliance on assessments based on numerical results obtained using computational methods, primarily because of improvements in the methods by which computational analyses are accomplished and because their relationship with the real world is now understood better than before.

Analytical methods are preferred over shock tests when shock tests are not considered possible or practical, for example in cases where

- the structure or equipment for which an assessment is required is excessively large or expensive;
- an assessment of shock resistance is required as part of the design process and/or for the purpose of testing and improving the model used by the designer;
- the designer needs analytical support in deciding whether and how to test the product for which an assessment is required;
- the designer is seeking a basis for generalizing the results of shock tests performed on a product or class of products; or

— the shock resistance can be assessed adequately by using simple mathematical models (for example, in shock isolation design or the layout of fastenings for shock-resistant installations).

Depending upon the mechanical behaviour and complexity of the product, its functional importance relative to other parts of the system in which it will be used, and the safety requirements imposed on the product or the system of which it is a part, the analytical approach selected to assess appropriately the product's shock resistance may be relatively simple or sophisticated. It may be as simple as

— an equivalent-static-load (g-load) analysis, or

— an analysis of simple models using the elastic and/or plastic deformation-energy capability of the model as a measure of the model's capability to accept without failure the energy associated with a shock-pulse input.

It may be as sophisticated as computational methods that make use of

— time history,

— finite elements, and

— analytical modal analysis.

In order to avoid misunderstandings between the customer and the supplier of an analytical assessment, many details need to be discussed and established concerning

a) the mechanical properties of the product and its environment (i.e. size, weight, material, method of construction or manufacture, operating conditions, safety, shock-sensitive components, pipe connections, fasteners, etc.);

b) the specification of the shock-input parameters, tolerance-limit requirements or other acceptance criteria;

c) the appropriate mathematical model, the adequacy of which can be measured by the model's capability for characterizing the mechanical properties of the product in terms of the least number of parameters required to yield useful results. These include the kind of force-deflection constraints (linear or non-linear, elastic or plastic, singly or in combination), the type of system or modal damping, the manner in which energy is propagated through the system, and the form and number of degrees of freedom of the model (lumped-parameter and finite, or continuous and infinite);

d) an appropriate method of analysis, frequency range of interest, and the purpose and limits of the investigation;

e) the method and style of presenting the results.

Sometimes the supplier is handicapped in applying his background knowledge properly because sufficient technical information is not or cannot be furnished by the customer; however, the customer should be aware of what he can expect from an analytical assessment.

Mechanical vibration and shock — Analytical methods of assessing shock resistance of mechanical systems — Information exchange between suppliers and users of analyses

1 Scope

This International Standard establishes the procedures for specifying the analytical methods which can be used to assess the shock resistance of mechanical systems (products or human subjects). It provides a protocol for conducting and documenting a shock analysis and identifies the requirements of the protocol.

It applies to any product or human subject for which an analytical assessment of its shock resistance is required.

NOTE 1 In this International Standard, unless noted otherwise, the term "product" is used to designate an engineering artifact (for example, equipment, component, machine, vehicle or structure).

NOTE 2 Neither the parameters characterizing the shock environments of concern nor acceptable levels of performance are associated with specific numerical values in this International Standard. When evaluating the shock resistance of a specific product to specific shock environments and/or levels of performance, it is necessary that appropriate numerical values be assigned to these parameters; this International Standard only establishes how such an evaluation can be carried out and does not specify the numerical values that could or should be assigned in any specific instance.

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

3 Definitions

For the purposes of this International Standard, the following definitions apply. Definitions taken from ISO 2041 are cited as quotations.

3.1 mechanical system

(1) In the field of mechanical shock, the mechanical configuration of a product, including all constraints and interactive parts of its environment which must be present or accounted for in order to describe adequately the mechanical behaviour of the mounted product and its components.

(2) "An aggregate of matter comprising a defined configuration of mass, stiffness and damping."

[ISO 2041:1990, 1.22]

3.2 shock resistance: The ability of a system to withstand shock excitation, given in terms of a specified shock pulse, where the system responses do not exceed specified acceptable limits.

NOTE 3 In quantitative terms, the shock resistance of a system is stated as the shock input values the system can accept without the responses of the system exceeding defined (quantified) acceptable limits.

3.3 (shock) performance criteria: The set of system response values or other functional criteria which define the acceptable performance of a product or human subject when it is subjected to impact loading.

NOTE 4 These response values may include stress, strain, strain rate and/or human tolerance.

3.4 modal analysis: An analytical procedure by which the response characteristics of a product or human subject are established (for example stress and strain in the elements of a structure or the shock resistance of a human subject) using quantitative measures of the parameters of mass, stiffness and damping assigned to each mode of a group of the lowest modes into which the model of a product or human subject is partitioned.

3.5 spectrum: "A description of a quantity as a function of frequency or wavelength.

NOTE — The term 'spectrum' may be used to signify a continuous range of components, usually wide in extent, which have some common characteristics, for example audio-frequency spectrum."

[ISO 2041:1990, 1.56]

NOTE 5 In the field of mechanical shock, spectra are not given as a function of wavelength.

3.6 mechanical shock; shock: "A sudden change of force, position, velocity or acceleration that excites transient disturbance in a system.

NOTE — The change is normally considered sudden if it takes place in a time that is short compared with the fundamental periods of concern."

[ISO 2041:1990, 3.1]

3.7 shock pulse; "A form of shock excitation characterized by a sudden rise and/or sudden decay of a time-dependent parameter (such as motion, force, or velocity).

NOTE — A descriptive mechanical term should be used, for example acceleration shock pulse."

[ISO 2041:1990, 3.2]

3.8 applied shock; shock excitation: "An excitation, applied to a system, that produces a mechanical shock."

[ISO 2041:1990, 3.3]

3.9 shock motion: "A transient motion causing, or resulting from, a shock excitation."

[ISO 2041:1990, 3.4]

3.10 impact: "A single collision of one mass with a second mass."

[ISO 2041:1990, 3.5]

3.11 impulse

"(1) The integral with respect to time of a force taken over the time during which the force is applied.

(2) For a constant force, the product of the force and the time during which the force is applied.

NOTE — In shock usage, the time-interval is short."

[ISO 2041:1990, 3.6]

3.12 bump: "A form of shock which is repeated many times for test purposes."

[ISO 2041:1990, 3.7]

3.13 ideal shock pulse: "A shock pulse that is described by a simple time function."

[ISO 2041:1990, 3.8]

3.14 nominal shock pulse; nominal pulse: "A specified shock pulse that is given with specified tolerances.

[NOTE 1] 'Nominal shock pulse' is a generic term. It requires an additional modifier to make its meaning specific, for example nominal half-sine shock pulse, or nominal sawtooth shock pulse.

[NOTE 2] The tolerances of the nominal pulse from the ideal may be expressed in terms of pulse shapes (including area), or corresponding spectra."

[ISO 2041:1990, 3.16]

3.15 nominal value of a shock pulse: "A specified value (for example peak value or duration) given with specified tolerances."

[ISO 2041:1990, 3.17]

3.16 duration of shock pulse: "The time-interval between the instant the motion rises above some stated fraction of the maximum value and the instant it decays to this fraction.

[NOTE 1] This definition is limited to pulses of simple shape.

[NOTE 2] For measured pulses, the 'stated fraction' is usually taken as 1/10. For ideal pulses, it is taken as zero."

[ISO 2041:1990, 3.18]

3.17 rise time; pulse rise time: "The interval of time required for the value of the pulse to rise from some specified small fraction of the maximum value to some specified large fraction of the maximum value.

NOTE — For measured pulses, the 'specified small fraction' is usually taken as 1/10 and the 'specified large fraction' as 9/10. For ideal pulses, the fractions are taken as 0 and 1,0."

[ISO 2041:1990, 3.19]

3.18 pulse drop-off time; pulse decay time: "The interval of time required for the value of the pulse to drop from some specified large fraction of the maximum value to some specified small fraction of the maximum value.

NOTE — For measured pulses, the 'specified small fraction' is usually taken as 1/10 and the 'specified large fraction' as 9/10. For ideal pulses, the fractions are taken as 0 and 1,0."

[ISO 2041:1990, 3.20]

3.19 shock testing machine: "A device for subjecting a system to controlled and reproducible mechanical shock."

[ISO 2041:1990, 3.23]

3.20 shock response spectrum

"(1) The description of the responses to an applied shock of a series of systems of a specified type as a function of their natural frequencies.

(2) As used in the field of mechanical shock, an expression that approximates the maximum responses (displacement, velocity or acceleration) to an applied shock of an assembly of linear single degree-of-freedom systems, as a function of their natural frequencies.

[NOTE 1] 'Shock response spectrum' is a generic term. It requires an additional modifier to make its meaning specific, for example acceleration or velocity or displacement shock response spectrum.

[NOTE 2] If the amount and kind of damping of the systems are not given, they are assumed to be zero. Unless otherwise indicated, the responses are maximum absolute values irrespective of sign and the time at which the maximum occurs. This is often referred to as a maximum shock response spectrum. If reference is made to other types of shock response spectra, this shall be stated.

[NOTE 3] It should be noted that the concept of a shock response spectrum is not fully consistent with the definition of spectrum" (see 3.5).

[ISO 2041:1990, 3.24]

4 Information to be supplied by the user of the analysis

4.1 General

The person carrying out the analysis (the supplier) shall be furnished with sufficient quantitative information on the product or human subject, and on the shock, environmental conditions and performance criteria so that he can select, in concert with the user, appropriate methods and models for carrying out the analysis. The essential information to be furnished depends upon the type of acceptance criteria and on the proposed analysis method. This information is generally detailed in an agreement between the customer and supplier.

A list of the minimum information needed to make an analytical assessment of the ability of a system to withstand shock should be given, even if only a simple analysis is required.

4.2 General description of the product

A brief description of the mechanical properties of the product or human subject should be given, including appropriate elements of its supporting structure. The description may be taken from

a) **drawings**, showing overall dimensions, structural details, materials and material composites, component connections and the orientation of components relative to each other or to a common reference;

b) **the characteristics of the supporting structure to be used with the product**, including how and where it is mounted (for example, with hold-down bolts or on resilient mountings on a ship or vehicle, or in a building or container), and the design properties and dimensions of the supporting structure, including its static and/or dynamic load capacity;

c) **the characteristics of connections and attachments**, including the stiffness and acceptable deflection amplitudes of connecting pipes, tubes, cables and other resilient devices that would be present under normal operating conditions, and the installation clearances;

d) **a description of the mass distribution of the product**, in terms of its main elements and, if possible, the moments of inertia of the product and of its main elements (in each case the method by which these data were obtained shall be given);

e) **relevant data obtained from analysis and tests performed earlier**, including the results of shock tests, static-load analyses, information related to the shock capability and other dynamic properties of structural elements;

f) **information on any limitations on transporting and/or operating the product.**

4.3 Shock environment conditions

The shock environment to be considered as input data for the analyses shall be stated clearly in terms of its severity, its direction, the points where it is applied to the product and its origin(s).

a) The **severity** of the shocks shall be given in terms suitable for the analyses. If applicable, standards based on idealized pulse shapes or design shock spectra should be used. For idealized pulse shapes, the shape of the pulse, its duration and its maximum amplitude (i.e. its maximum value of acceleration, velocity or displacement) shall be stated. For other pulse shapes, the time history of the pulse (i.e. acceleration as a function of time) is useful for most analyses. If available, additional information (such as mean-square spectra) should be furnished. When the applied shock is associated with a test in which the product is dropped, the drop height and the type of surface onto which the product is dropped (for example, ground, concrete or into water) shall be stated.

b) The **direction(s)** in which the shocks are applied shall be stated, relating them to the horizontal and vertical planes of the object to which the product is to be fastened.

c) Normally, the **points** on the product which receive the shock are the attachment (feet). When the shocks are associated with dropping the product, the surfaces or corners that may receive the shock shall be stated.

d) The **origin(s)** of the data shall be stated.

NOTE 6 Those carrying out the analyses are often sufficiently familiar with technical developments in the area of shock measurements to serve as monitors of the correctness of the data furnished by a customer.

4.4 (Shock) performance criteria

Failure or acceptance criteria associated with the product and/or its structural elements shall be stated. They may be expressed in terms of acceptable responses, functional performance criteria and safety requirements.

a) **Acceptable responses** may be related to stress levels, deflections, forces, plastic deformation, etc. If different responses can be accepted by the product at different points, this shall be stated.

b) **Functional performance criteria** may include acceptable deviations from normal function during application of the shock. In some cases, it may not be necessary or required that the product should function *during* application of the shock. Normally, it is required that the product be capable of functioning without deviation from its norms *after* having been subjected to shocks.

c) **Safety requirements** may be appropriate for human subjects and for products that contain explosives, dangerous liquids, etc., or if secondary damage or hazards may be caused by malfunctions of the product attributable to shocks applied during a test.

5 Information to be furnished in a report by the person carrying out the analysis

5.1 Description of the selected mathematical model and method of analysis, and a rationale for the selection

The mathematical model selected by the person carrying out the analysis shall be given with a rationale for its selection. The model should show the essential features of the mass, stiffness and damping characteristics of the product in sufficient detail to make the usefulness of the selected model clear. The numerical values assigned to the mass, stiffness and damping characteristics of the model of the product and/or its main elements should be sensibly self-contained, internally consistent and, where possible, their relationship to the geometry and materials of the actual product should be shown and explained.

The points on the model at which the shock excitation will be applied should be identified clearly. The environment of the product model in which the shock resistance of the product will be tested (i.e. the mechanical characteristics of the foundation and substructure, if any, to which the product model is attached) should be stated clearly. Any interactions of the product with its environment should be stated and explained, particularly any interactions which could affect the operation of the product in the stated environment during or after the shock test.

The method of analysis shall be described in terms of the procedural requirements for conducting the analysis, the assumptions on which the method is based and the form and substance of the numerical results the method will generate. Any limitations on the analysis imposed by the model or assumptions, or both, shall be stated and explained.

The rationale is given to explain the reasons for making each choice related to the product model and its environment and to explain each decision related to the assumptions which limit the scope of the analysis. Where possible, the explanations offered in the rationale should be documented by references to published technical literature. The rationale should be written in a manner, style and at a level readily understandable by the customer's engineers who will interpret the assessment.

Where possible, single-figure, go/no go measures of merit should be used in the assessment of a product's resistance to shock. If the assessment requires the interpretation of a profile of inputs and/or responses, this should be explained.

5.2 Acceptable levels of performance

This International Standard does not specify or suggest what should be acceptable response and/or performance levels of products and human subjects to shock inputs. If such information is available elsewhere, either in other standards or in accepted and recognized professional technical literature known to the supplier of the analysis, the availability and sources of this information should be appended to the assessment. The supplier of the analysis should anticipate that he may be requested to interpret his assessment in terms of these acceptable levels of performance for the specific product involved.

6 Responsibility for design changes resulting from interpretation of an assessment

Any design changes that result from interpretations of an assessment (see 5.2) are the sole responsibility of the user of the analysis (presumably, the manufacturer of the product). Such design changes could result in physical changes in the product with corresponding changes in the product model and/or the numerical values of mass, stiffness and damping assigned to its main elements. Any continuing assessment which takes these changes into account should be the subject of separate negotiation and, perhaps, a new contractual arrangement between the supplier and user of this new assessment.