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Vibration generating machines — Guidance for selection —

Part 4: Equipment for multi-axial environmental testing

Générateurs de vibrations — Lignes directrices pour la sélection —

Partie 4: Équipement pour les essais environnementaux multi-axiaux

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

A list of all parts in the ISO 10813 series can be found on the ISO website.

Introduction

Selection of a suitable vibration generating system is an urgent problem as one needs to purchase new test equipment or to update the equipment already at one's disposal to perform a certain test or to choose from among the equipment proposed by a test laboratory or even a laboratory itself which offers its service to carry out such a test. A problem like this can be resolved only if a number of factors are considered simultaneously, as follows:

— type of test to be carried out (environmental testing, normal and/or accelerated, dynamic structural testing, diagnosis, calibration, etc.);

— requirements to be followed;

— test conditions (single or multiple excitation, one mode of vibration or combined vibration, single or combined test, for example, dynamic plus climatic, etc.);

— objects to be tested.

This document deals only with equipment to be used for multi-axial environmental testing, and procedures of the selection are predominant to meet the requirements of this testing.

Because the multi-axial environmental test system is composed of more than one exciter, ISO 10813-1 should be used along with this document to select the proper exciters. It is presumed in this document that the system to be selected will be able to drive the object under test up to a specified level. In order to generate an excitation without undesired motions, a suitable control system should be used, however selection of a control system lays beyond the scope of this document.

It should be emphasized that vibration generating systems are complex machines, so the correct selection always demands a certain degree of engineering judgement. As a consequence the purchaser, when selecting the vibration test equipment, may resort to the help of a third party. In such a case, this document can help the purchaser to ascertain if the solution proposed by the third party is acceptable or not. Designers and manufacturers can also use this document to assess the market environment.

Vibration generating machines — Guidance for selection —

Part 4: Equipment for multi-axial environmental testing

1 Scope

This document gives guidance for the selection of vibration generating equipment for multi-axial environmental testing, depending on the test requirements.

Multi-axial environmental test equipment dealt with in this document refers to a vibration test system having controlled vibration of more than one degree of freedom, including linear vibration and angular vibration. In this document, one or more exciter per desired degree of freedom is supposed.

The guidance covers such aspects of selection as

— number, type and models of exciters,

— number, type and models of connectors,

— system configuration, and

— some components.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

ISO 10813-1, *Vibration generating machines — Guidance for selection — Part 1: Equipment for environmental testing*

ISO 15261, *Vibration and shock generating systems — Vocabulary*

3 Terms and definitions

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

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

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

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

3.1
exciter
vibration generator
excitation source where vibratory forces are generated

3.2
table
platform on which specimens or fixtures are mounted

3.3
multi-exciter system
vibration generating system which includes two or more *exciters* (3.1) and a control system to coordinate the motion

3.4
connector
device used to transmit the excitation force from *exciters* (3.1) to the *table* (3.2) or specimens with the capability of decoupling the linear motions between *exciters* (3.1)

3.5
spherical connector
connector (3.4) with spherical joints

Note 1 to entry: Normally spherical connector has one or two spherical joints (see Figure 7).

3.6
planar connector
connector (3.4) having planar restriction which is capable of moving in two orthogonal axes in that plane

Note 1 to entry: Some planar connectors also have another single-degree-of-freedom (1-DOF) rotational motion in the plane.

3.7
drive rod
stinger
rod with a large length-diameter ratio, stiff in the longitudinal direction and flexible in the transverse direction

3.8
parasitic motion
undesired motion of the *table* (3.2) that occurs when multi-axial excitation is carried out over the *table* (3.2)

3.9
guidance system
mechanical device used to guide the *exciter* (3.1) to move in the axial direction, providing transverse motion restraint to the *exciter* (3.1)

4 Requirements for multi-axial environmental tests

4.1 Multi-axial vibration test motivation

In the real world, pure single axis vibration does not exist, meaning that the real vibration environment is multi-axial. However due to test equipment restrictions, multi-axial vibration testing is mainly conducted one axis after another sequentially, which has different impacts on the specimens than multi-axial simultaneous vibration tests. It is reported that some devices failed in the real multi-axial environment after single axis vibration testing was conducted with no abnormities observed. Therefore, to simulate the real vibration environment and help discover the product malfunction rationale due to multi-axial vibration, the need to conduct a real multi-axial vibration testing has been growing dramatically.

The most common reasons to conduct a multi-axial vibration test are listed below[4][5]:

— Distributed multi-axial vibration or shock energy is applied over the specimen in a controlled manner without relying on the dynamics of the specimens for such distribution.

— Multi-axial testing can be selected when the specimen has a high slenderness ratio for energy distribution considerations.

— Multi-exciter system is selected to increase the thrust force in order to achieve the desired vibration level for large and heavy specimens.

— Some multi-axial vibration test systems are constructed to increase the overall test efficiency because the tests of different axes can be conducted simultaneously rather than sequentially.

— Multi-axial vibration testing is conducted on inertial measurement units which are subject to linear and angular vibration and the measuring accuracy is highly dependent on the multi-axial environment.

— Multi-axial vibration testing is conducted in several directions rotationally or translationally to meet test criteria or to reproduce in-service measurement data, such as automotive or earthquake simulations.

— Multi-axial vibration testing can be selected to avoid the need to design and fabricate a very expensive fixture that may be used only once.

— Multi-axial vibration testing can be selected to provide a compensating force to counteract large overturning moments, which may occur during testing of tall structures, such as satellites with several meters of height of centre of gravity.

4.2 Test waveforms

Multi-axial vibration testing mainly deals with the following waveforms:

— wide-band random;

— time history waveform replication.

NOTE Sinusoidal testing, including swept and fixed frequency sinusoidal testing, is not common in practice for multi-axial configuration, but is achievable.

4.3 Types of multi-axial environmental testing

4.3.1 General

Typical multi-axial environmental vibration testing includes the following types.

4.3.2 Parallel thrust testing

Parallel thrust testing is used to excite one specimen at multiple points in parallel directions. The purpose is to simulate the real multi-excitation parallel working environment. Typical tests include automobile vibration testing through four wheels under independent excitations and missile vibration testing through dual excitation points.

4.3.3 Bi-axial vibration testing

The purpose of bi-axial vibration testing is to excite the specimen from two orthogonal directions. It is a simplified condition of tri-axial vibration testing, which is suitable when the specimen is firmly constrained in one direction and therefore the vibration in that direction has little impact. The two orthogonal directions can be two horizontal directions or one horizontal and one vertical direction.

4.3.4 Tri-axial vibration testing

The purpose of tri-axial vibration testing is to excite the specimen from three orthogonal directions to simulate the actual tri-axial vibration environment for most real-world objects when rotational excitations are not considered.

4.3.5 Six-degrees-of-freedom vibration testing

The purpose of six-degrees-of-freedom (6-DOF) vibration testing is to simulate a complete 6-DOF spatial vibration of a specimen, including three-degrees-of-freedom (3-DOF) of linear vibration and 3-DOF of angular vibration. It is useful for specimens which are sensitive to angular vibration such as inertial measurement units.

4.3.6 Other multi-degrees-of -freedom testing

Depending on conditions of the actual vibration environment, any number of degrees of freedom (DOFs), but no less than 2 and no more than 6 per excitation point, may be required to conduct the test.

5 Multi-axial vibration test equipment

5.1 Types of multi-axial vibration test equipment

5.1.1 General

In order to meet various multi-axial vibration testing requirements, many kinds of test equipment have been developed. Typical types of multi-axial vibration test equipment are listed in 5.1.2 to 5.1.6.

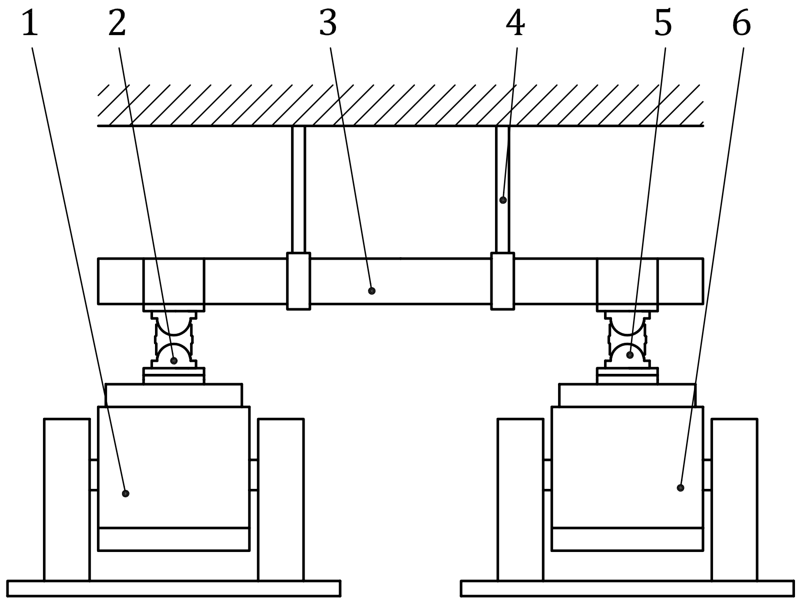
5.1.2 Parallel thrust equipment

In order to produce the force required for a test which cannot be satisfied by single exciters or to adapt to testing slender specimens, multiple exciters are aligned in parallel. The exciters can be controlled in or out of synchronization or completely independently. Angular vibration can be generated when exciters are driven at different amplitudes or phases. The selection of an amplitude and phase synchronized multi-exciter test system can be considered as the selection of a single vibration generator (see ISO 10813-1), and is therefore not included in this document. Figure 1 shows an example of a parallel thrust configuration in which a slender specimen is excited vertically by two independent exciters at two excitation points with connectors decoupling motion contradictions brought about by exciter asynchrony. A suspension device is applied to offset the specimen mass.

5.1.3 Bi-axial linear vibration equipment

Bi-axial linear vibration equipment is composed of two exciters in orthogonal coordinates. Linear vibration testing in two orthogonal directions can be generated simultaneously and angular vibration test cannot be performed. Figure 2 shows an example of a bi-axial linear vibration configuration, in which two exciters are arranged in a vertical/horizontal manner. The table is linked with the two exciters through the two connectors. Adapters can be employed when necessary to couple the table with the connectors.

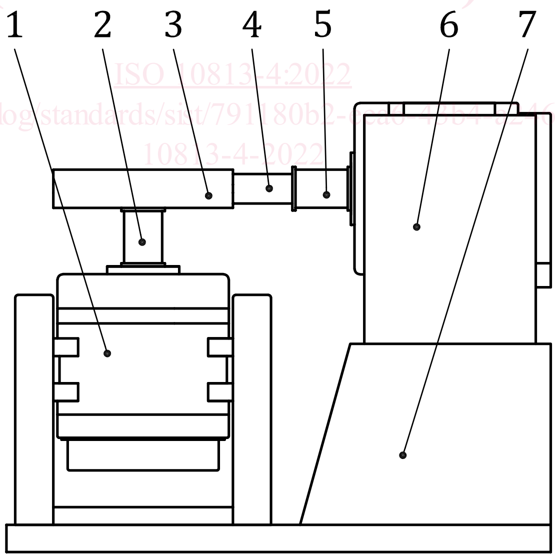
NOTE There are occasions when two exciters are not available or it is too expensive to construct a real bi-axial test system. “Bi-axial” testing can be conducted by a one exciter configuration, in which the axis of the exciter is at a specific angle, i.e. 45°, with respect to the two concerning axes. This method is essentially a single axis test but can be taken as a synchronized bi-axial test as well. See IEC 60068-3-3[3] for a detailed description of this method.



Key

1 exciter 1
2 connector 1
3 specimen
4 suspension
5 connector 2
6 exciter 2

Figure 1 — Example of parallel thrust equipment



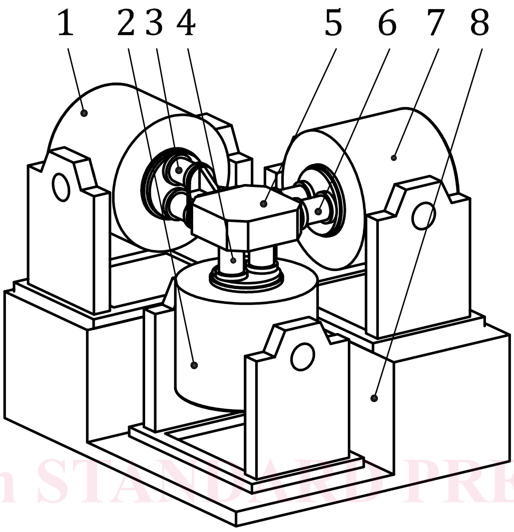
Key

1 exciter 1
2 connector 1
3 table
4 adaptor
5 connector 2
6 exciter 2
7 pedestal

Figure 2 — Example of bi-axial linear vibration equipment

5.1.4 Tri-axial linear vibration equipment

Tri-axial linear vibration equipment is composed of many exciters in three orthogonal coordinates. Simultaneous rectilinear vibrations in three orthogonal directions can be generated and angular vibration test cannot be performed. Figure 3 shows an example of a tri-axial linear vibration configuration, in which three exciters are arranged in a Cartesian coordinate. In this example, 6 dual sphere connectors are used to decouple the table motion and restrain unwanted motions. Air spring isolations are placed between the equipment and the ground to reduce vibration transmission to the laboratory.



Key

1 exciter 1
2 exciter 2
3 connectors 1’ and 1’’
4 connectors 2’ and 2’’
5 table
6 connectors 3’ and 3’’
7 exciter 3
8 pedestal

Figure 3 — Example of three-exciters in orthogonal coordinate configuration

NOTE There are occasions when more than two exciters are not available or it is too expensive to construct a real tri-axial test system. “Tri-axial” testing can be conducted by two exciter configurations, in which one exciter is vertically assigned and the other is horizontally assigned. This method is essentially a bi-axial test but can be taken as a synchronized tri-axial test as well. See IEC 60068-3-3 for a detailed description of this method.

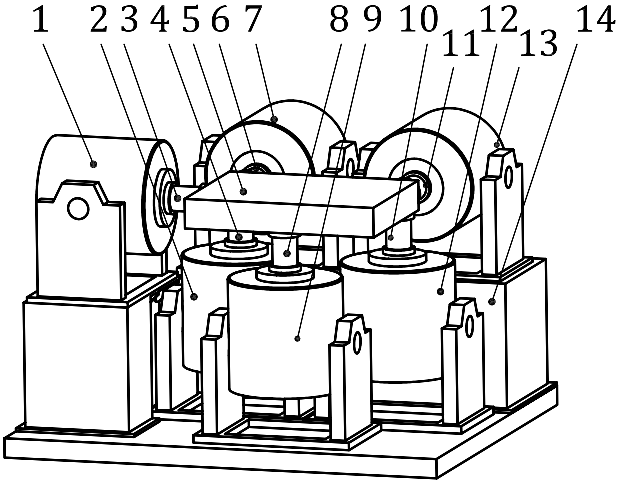
5.1.5 Six-degrees-of-freedom test equipment

The 6-DOF test equipment is composed of no less than six exciters. At least two exciters are required to act in parallel to generate an angular vibration. The basic motion 6-DOF equipment can generate includes linear vibration in the three orthogonal axes and three angular vibrations about the orthogonal axes. By controlling the basic motion properly, spatial in-axis or out-of-axis translational and rotational vibration can be generated.

Typical 6-DOF test systems can be configured as follows:

— System composed of 6 exciters in orthogonal coordinate with three exciters in the vertical direction, other three exciters in horizontal directions (two in X axis, one in Y axis), shown in Figure 4.

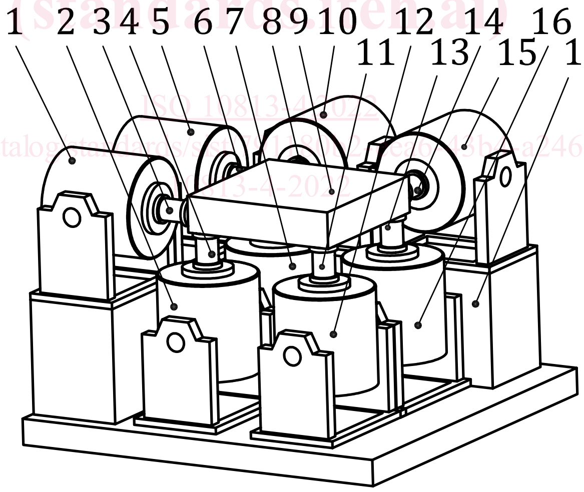
— System composed of 8 exciters in orthogonal coordinate with four exciters in the vertical direction, other four exciters in horizontal directions (two for each axis), shown in Figure 5.



Key

1	exciter 1
2	exciter 2
3	connector 1
4	connector 2
5	table
6	connector 3
7	exciter 3
8	connector 4
9	exciter 4
10	connector 5
11	connector 6
12	exciter 5
13	exciter 6
14	pedestal

Figure 4 — Example of a 6-DOF vibration system composed of 6 exciters and 6 connectors



Key

1	exciter 1
2	exciter 2
3	connector 1
4	connector 2
5	exciter 3
6	connector 3
7	exciter 4
8	connector 5
9	table
10	exciter 5
11	connector 6
12	exciter 6
13	connector 7
14	connector 8
15	exciter 8
16	exciter 7
17	pedestal

NOTE Connector 4 is hidden.

Figure 5 — Example of a 6-DOF vibration system composed of 8 exciters and 8 connectors

NOTE The exciters can be any type in practice although the examples given in Figures 1 to 5 take electrodynamic vibration generators as exciters.