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ISO 7626-2

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Vibration and shock — Experimental determination of mechanical mobility —

Part 2 : Measurements using single-point translation excitation with an attached vibration exciter

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Vibrations et chocs — Détermination expérimentale de la mobilité mécanique —

Partie 2 : Mesurages avec utilisation d'une excitation de translation en un seul point, au moyen d'un générateur de vibrations solidaire de ce point

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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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

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International Standard ISO 7626-2 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock.*

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ISO 7626 will consist of the following parts, under the general title *Vibration and shock — Experimental determination of mechanical mobility*:

— *Part 1: Basic definitions and transducers*

— *Part 2: Measurements using single-point translation excitation with an attached vibration exciter*

— *Part 3: Mobility measurements using rotational excitation at a single point*

— *Part 4: Measurements of the entire mobility matrix using attached exciters*

— *Part 5: Measurement using impact excitation with an exciter which is not attached to the structure*

— *Part 6: Mobility data interchange format*

— *Part 7: Modal parameter estimation*

Annexes A and B form an integral part of this part of ISO 7626. Annexes C and D are for information only.

Introduction

General introduction to ISO 7626 on mobility measurement

Dynamic characteristics of structures can be determined as a function of frequency from mobility measurements or measurements of the related frequency-response functions, known as accelerance and dynamic compliance. Each of these frequency-response functions is the phasor of the motion response at a point on a structure due to a unit force (or moment) excitation. The magnitude and the phase of these functions are frequency-dependent.

Accelerance and dynamic compliance differ from mobility only in that the motion response is expressed in terms of acceleration or displacement, respectively, instead of in terms of velocity. In order to simplify the various parts of ISO 7626, only the term "mobility" will be used. It is understood that all test procedures and requirements described are also applicable to the determination of accelerance and dynamic compliance.

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Typical applications for mobility measurements are for:

a) predicting the dynamic response of structures to known or assumed input excitation;

b) determining the modal properties of a structure (natural frequencies, mode shapes and damping ratios);

c) predicting the dynamic interaction of interconnected structures;

d) checking the validity and improving the accuracy of mathematical models of structures;

e) determining dynamic properties (i.e. the complex modulus of elasticity) of materials in pure or composite forms.

For some applications, a complete description of the dynamic characteristics may be required using measurements of translational forces and motions along three mutually perpendicular axes as well as measurements of moments and rotational motions about these three axes. This set of measurements results in a 6×6 mobility matrix for each location of interest. For N locations on a structure, the system thus has an overall mobility matrix of size $6N \times 6N$.

For most practical applications, it is not necessary to know the entire $6N \times 6N$ matrix. Often it is sufficient to measure the driving-point mobility and a few transfer mobilities by exciting with a force at a single point in a single direction and measuring the translational response motions at key points on the structure. In other applications, only rotational mobilities may be of interest.

In order to simplify the use of the various parts of ISO 7626 in the various mobility measurement tasks encountered in practice, ISO 7626 will be published as a set of five separate parts.

ISO 7626-1 covers basic definitions and transducers. The information in ISO 7626-1 is common to most mobility measurement tasks.

ISO 7626-2 (this part of ISO 7626) covers mobility measurements using single-point translational excitation with an attached exciter.

ISO 7626-3 covers mobility measurements using single-point rotational excitation with an attached exciter. This information is primarily intended for rotor system rotational resonance predictions.

ISO 7626-4 covers measurements of the entire mobility matrix using attached exciters. This includes the translational, rotational and combination terms required for the 6 × 6 matrix for each location on the structure.

ISO 7626-5 covers mobility measurements using impact excitation with an exciter which is not attached to the structure.

Mechanical mobility is defined as the frequency-response function formed by the ratio of the phasor of the translational or rotational response velocity to the phasor of the applied force or moment excitation. If the response is measured with an accelerometer, conversion to velocity is required to obtain the mobility. Alternatively, the ratio of acceleration to force, known as accelerance, may be used to characterize a structure. In other cases, dynamic compliance, the ratio of displacement to force, may be used.

NOTE — Historically, frequency-response functions of structures have often been expressed in terms of the reciprocal of one of the above-named dynamic characteristics. The arithmetic reciprocal of mechanical mobility has often been called mechanical impedance. It should be noted, however, that this is misleading because the arithmetic reciprocal of mobility does not, in general, represent any of the elements of the impedance matrix of a structure. This point is elaborated upon in ISO 7626-1.

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Mobility test data cannot be used directly as part of an impedance model of the structure. In order to achieve compatibility of the data and the model, the impedance matrix of the model shall be converted to mobility or *vice versa* (see ISO 7626-1 for limitations).

Introduction to this part of ISO 7626

For many applications of mechanical mobility data, it is sufficient to determine the driving-point mobility and a few transfer mobilities by exciting the structure at a single location, in a single direction, and measuring the translational response motions at key points on the structure. The translational excitation force may be applied either by vibration exciters attached to the structure under test or by devices that are not attached.

Categorization of excitation devices as "attached" or "unattached" has significance in terms of the ease of moving the excitation point to a new position. It is much easier, for example, to change the location of an impulse applied by an instrumented hammer than it is to relocate an attached vibration exciter to a new point on the structure. Both methods of excitation have applications to which they are best suited. This part of ISO 7626 deals with measurements using a single attached exciter; measurements made by impact excitation without the use of attached exciters are covered by ISO 7626-5.

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Vibration and shock — Experimental determination of mechanical mobility —

Part 2 :
Measurements using single-point translational excitation with an attached vibration exciter

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1 Scope

This part of ISO 7626 specifies procedures for measuring mechanical mobility and other frequency-response functions of structures, such as buildings, machines and vehicles, using a single translational vibration exciter attached to the structure under test for the duration of the measurement.

It is applicable to measurements of mobility, accelerance, or dynamic compliance, either as a driving-point measurement or as a transfer measurement. It also applies to the determination of the arithmetic reciprocals of those ratios such as free effective mass. Although excitation is applied at a single point, there is no limit on the number of points at which simultaneous measurements of the motion response may be made. Multiple-response measurements are required, for example, for modal analyses.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 7626. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 7626 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2041 : 1975, *Vibration and shock — Vocabulary.*

ISO 4865 : —[1], *Vibration and shock — Methods for analysis and presentation of data.*

ISO 5344 : 1980, *Electrodynamic test equipment for generating vibration — Method of describing equipment characteristics.*

ISO 7626-1 : 1986, *Vibration and shock — Experimental determination of mechanical mobility — Part 1: Basic definitions and transducers.*

3 Definitions

For the purposes of this part of ISO 7626, the definitions given in ISO 7626-1 and ISO 2041 apply; certain terms pertaining to digital data analysis are defined in ISO 4865. For convenience, the most important definitions used in this part of ISO 7626 are given in 3.1 to 3.5.

1) To be published.

3.1 frequency-response function: The frequency-dependent ratio of the motion-response phasor to the phasor of the excitation force.

NOTES

1 Frequency-response functions are properties of linear dynamic systems which do not depend on the type of excitation function. Excitation can be harmonic (i.e. sinusoidal), random or transient functions of time. The test results obtained with one type of excitation can thus be used for predicting the response of the system to any other type of excitation. Phasors and their equivalents for random and transient excitation are discussed in annex B of ISO 7626-1 : 1986.

2 Linearity of the system is a condition which, in practice, will be met only approximately, depending on the type of system and on magnitude of the input. Care has to be taken to avoid non-linear effects.

3 Motion response may be expressed in terms of either velocity, acceleration, or displacement; the corresponding frequency-response function designations are mobility, accelerance, and dynamic compliance, respectively.

4 This definition has been taken from ISO 7626-1 : 1986.

3.2 mobility : The frequency-response function formed by the ratio of the velocity-response phasor to the excitation-force phasor or, in other words, the ratio of the velocity-response spectrum to the excitation-force spectrum.

The required boundary conditions are that no forces are applied to any point on the structure other than the exciting force at the driving point.

3.3 driving-point mobility, Y_{jj} **:** The frequency-response function formed by the ratio, in metres per newton second, of the velocity-response phasor at point j to the excitation force phasor applied at the same point with all other measurement points on the structure allowed to respond freely without any constraints other than those constraints which represent the normal support of the structure in its intended application.

NOTES

1 The term "point" designates a location and a direction. The term "coordinate" has also been used with the same meaning as "point".

2 This definition has been taken from ISO 2041 : 1975.

3.4 transfer mobility, Y_{ij} **:** The frequency-response function formed by the ratio, in metres per newton second, of the velocity-response phasor at point i to the excitation force phasor applied at point j with all points on the structure, other than j, allowed to respond freely without any constraints other than those constraints which represent the normal support of the structure in its intended application.

NOTE — This definition has been taken from ISO 2041 : 1975.

3.5 frequency range of interest: Span, in hertz, from the lowest frequency to the highest frequency at which mobility data are to be obtained in a given test series.

NOTE — This definition has been taken from ISO 7626-1 : 1986.

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4 Overall configuration of the measurement system

Individual components of the system used for mobility measurements carried out in accordance with this part of ISO 7626 shall be selected to suit each particular application.

However, all such systems should include certain basic components arranged as shown in figure 1. Requirements for the characteristics and usage of those components are given in the relevant clauses.

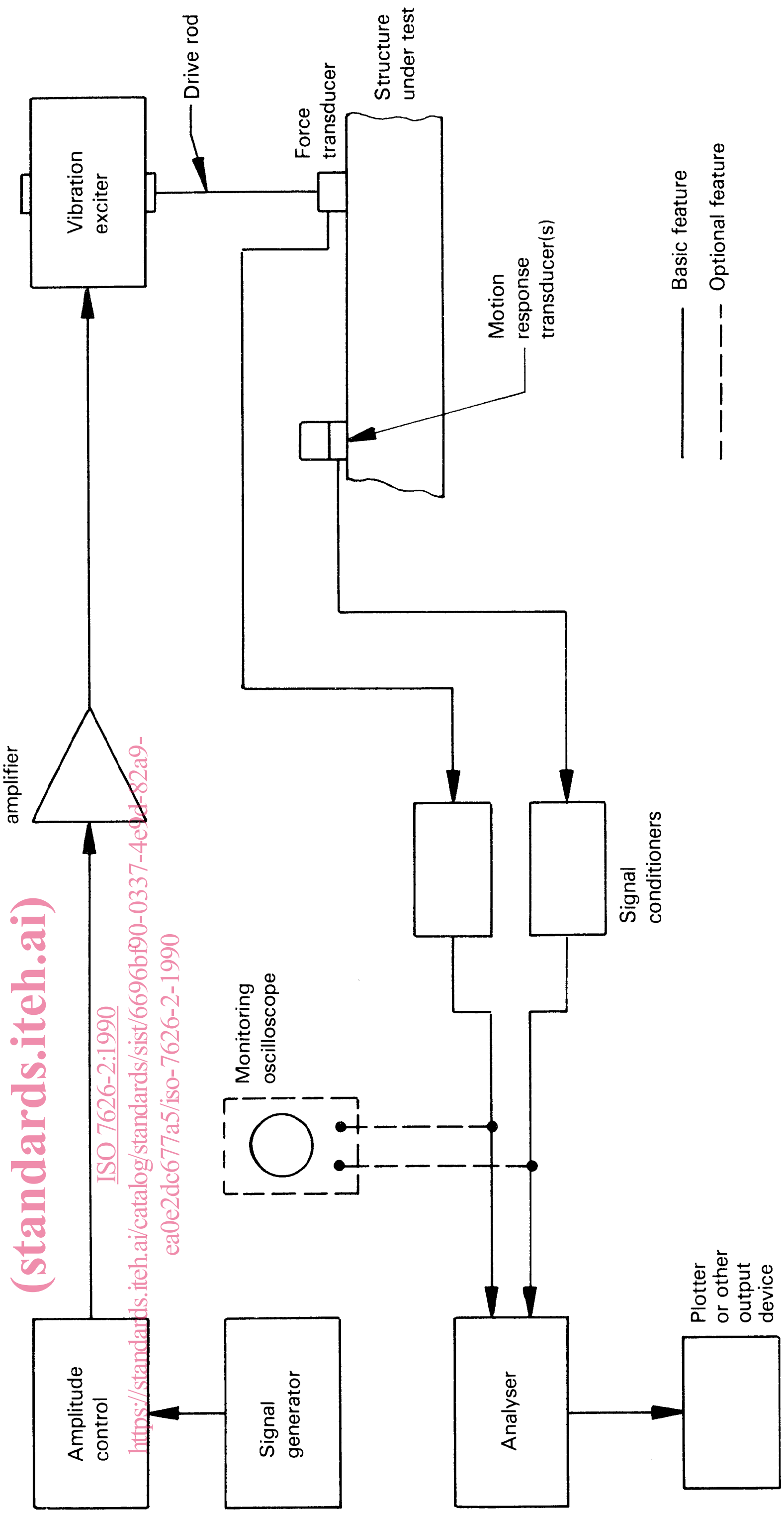

Figure 1 — Block diagram of mobility measurement system

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5 Support of the structure under test

5.1 General

Mobility measurements are performed on structures either in an ungrounded condition (freely suspended) or in a grounded condition (attached to one or more supports), depending on the purpose of the test. The constraints on the structure induced by the application of the vibration exciter are dealt with in 6.4.

5.2 Grounded measurements

The support of the test structure shall be representative of its support in typical applications unless it has been specified otherwise. A description of the support should be included in the test report.

5.3 Ungrounded measurements

A compliant suspension of the test structure shall be used. The magnitudes of all relevant elements of the driving-point mobility matrix of the suspension, at its point(s) of attachment to the structure under test, should be at least ten times greater than the magnitudes of the corresponding elements of the mobility matrix of the structure at the same attachment point(s). Details of the suspension system used shall be included in the test report.

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In the absence of quantitative information, design of the suspension is largely a matter of judgment. As a minimum requirement, all resonance frequencies of the rigid-body modes of the suspended structure shall be less than half the lowest frequency of interest.

Items commonly used to provide compliant suspension include shock cords and resilient pads of material such as foam and rubber. Since some suspension systems have mass but little damping, care shall be taken to ensure that the frequencies of the suspension resonances are well away from the modal frequencies of the test structure itself. The masses of any suspension components, such as hooks and turnbuckles, located close to the structure under test shall also be less than one-tenth of the free effective mass of the structure at each frequency of interest.

Preliminary testing should be performed to identify locations for the attachment of the suspension with the minimum possible effect on the intended measurements. Suspension near nodal points of the structure under test will minimize the interaction of the suspension system with the structure. Suspension cables should run normal to the direction of excitation, if practical, and even in this case, transverse string vibrations of suspension cables can affect the data.

NOTE — Attention should also be paid to any added damping of the structure due to the suspension system.

6 Excitation

6.1 General

Any excitation waveform, the spectrum of which covers the frequency range of interest, can be used provided that the excitation and response signals are processed properly.

Early investigators used sinusoidal excitation signals; under ideal conditions, the steady-state response then is also a sinusoidal signal. The ratio of the amplitudes of the sinusoidal response and the excitation signals yields the modulus of the mobility at that particular frequency and the phase difference is the argument.

This technique works because the amplitude of a sinusoidal signal is the modulus of the Fourier transform of that signal, so that excitation in itself accomplishes the same end as Fourier transformation of more complex signals. However, it is necessary to dwell at each excitation frequency long enough to reach the steady-state response. This is not necessary if the Fourier transforms of the excitation signal and of the response velocity are determined. A short duration sine burst can then be used and the ratio of the response and force spectra gives a correct mobility value over a limited frequency range.

The same will hold in case of swept-sine excitation : if Fourier transforms are applied, the sweep rate limitations mentioned in 9.2.3 are no longer relevant and the slowly swept-sine signal can be replaced by a fast swept-sine signal.

When applying digital Fourier transforms it is rather easy to use periodic excitation signals, for example periodic chirp or periodic random. The advantage is that time-domain leakage can be prevented easily.

6.2 Excitation waveforms

6.2.1 General

Applicable excitation waveforms include, but are not limited to, those described in 6.2.2 to 6.2.5. This part of ISO 7626 reflects technology in wide use during its drafting and no attempt was made to include emerging or research-oriented measurement methods. Comparative advantages and disadvantages of the different types of waveforms are discussed in [1].

6.2.2 Discretely stepped sinusoidal excitation

The excitation for a given measurement consists of a set of individual discrete-frequency sinusoidal signals, applied sequentially. The frequencies of the signals are incrementally spaced over the frequency range of interest; requirements for selecting the frequency increment are given in 9.2.2. At each frequency, the excitation is applied over a small interval of time. The length of the time interval shall be sufficiently long to achieve steady-state response of those natural vibration modes of the structure that are excited at the particular frequency and to achieve proper processing of the signal.

6.2.3 Slowly swept sinusoidal excitation

The excitation for a given measurement is a sinusoidal signal continuously swept in frequency from the lower to the upper limit of the frequency range of interest. The rate at which the frequency is swept shall be slow enough to achieve quasi-steady-state response of the structure; requirements for selecting the sweep rate are given in 9.2.3. Over a small interval of time, the energy of excitation is concentrated in the small frequency band swept during that interval.

6.2.4 Stationary random excitation

The waveform of stationary random excitation has no explicit mathematical representation, but does have certain statistical properties. The spectrum of the excitation signal shall be specified by the spectral density of the exciting force. Recommendations for shaping the spectral density to concentrate the excitation in the frequency range of interest are given in 9.4.3. All vibration modes having frequencies within this frequency range are excited simultaneously.

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6.2.5 Other excitation waveforms

Additional types of waveforms, described in 6.2.5.1 to 6.2.5.4, also simultaneously excite all vibration modes within a frequency band of interest. The methods of signal processing and excitation control used in conjunction with these waveforms are similar to those used with stationary-random excitation. These waveforms are repetitive and are recommended when synchronous time-domain averaging of the response waveform is necessary to measure properly the motion response of the structure.

6.2.5.1 Pseudo-random excitation

The excitation signal is synthesized digitally in the frequency domain to attain a desired spectrum shape. An inverse Fourier transformation of the spectrum may be performed to generate repetitive digital signals which are then converted to analogue electrical signals to drive the vibration exciter.

6.2.5.2 Periodic-chirp excitation

A periodic chirp is a rapid repetitive sweep of a sinusoidal signal in which the frequency is swept up or down between selected frequency limits. The signal may be generated either digitally or by a sweep oscillator and should be synchronized with the signal processor for waveform averaging to improve the signal-to-noise ratio.

6.2.5.3 Periodic-impulse excitation

A suitably shaped impulse function, usually generated digitally, is periodically repeated. The signal processor should be synchronized with the signal generator. The impulse function shape (typically half-sine or decaying step functions) shall be chosen to meet the excitation frequency requirements.

6.2.5.4 Periodic-random excitation

A periodic-random excitation combines the features of pure random and pseudo-random excitation in that it satisfies the conditions for a periodic signal yet changes with time so that it excites the structure in a purely random manner; this is done by using different pseudo-random excitation for each average.

6.3 Vibration exciters

Devices commonly attached to the structure under test to apply input forces having desired waveforms include electrodynamic, electrohydraulic, and piezoelectric vibration exciters (see ISO 5344). The frequency ranges of general applicability for each type of exciter are shown in figure 2.

The basic requirement of a vibration exciter is that it shall provide a sufficient force and displacement capability so that mobility measurements may be made over the entire frequency range of interest with an adequate signal-to-noise ratio. A larger vibration exciter may be required to apply adequate broad-band random excitation to a given structure than is needed for sinusoidal excitation. Smaller exciters may be used if a band limiting of the random noise is selected or if time-domain averaging of the excitation and response signal waveforms is used (see 6.2.5).

NOTE — The coherence function may be used as a measure of the adequacy of the vibration exciter in relation to background and electronic noise.

The excitation-force input to a structure gives rise to a reaction force which is provided either by the exciter support or by the inertia of the exciter itself; these approaches are illustrated in figures 3a) and b). If necessary, an additional mass should be attached to the exciter. An incorrect set-up which would allow transmission of exciter reaction forces to the structure via a path other than through the force transducer, i.e. through a common base on which both the exciter and the structure are mounted, is illustrated in figure 3c).