BS ISO 7626-5:2019

BSI Standards Publication

Mechanical vibration and shock — Experimental determination of mechanical mobility

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

Documents
Document Sharing Hub

Full document details: BS ISO 7626-5:2019

National foreword

This British Standard is the UK implementation of ISO 7626-5:2019. It supersedes BS 6897-5:1995, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GME/21/3, Whole body vibration and shock.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2020
Published by BSI Standards Limited 2020

ISBN 978 0 580 94341 6

ICS 17.160

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2020.

Amendments/corrigenda issued since publication

Date	Text affected

Documents
Document Sharing Hub

Full document details: BS ISO 7626-5:2019

INTERNATIONAL STANDARD

ISO 7626-5

Second edition
2019-12

Mechanical vibration and shock — Experimental determination of mechanical mobility —

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

Vibrations et chocs mécaniques — Détermination expérimentale de la mobilité mécanique —

Partie 5: Mesurages à partir d'une excitation par choc appliquée par un excitateur non solidaire de la structure

Reference number
ISO 7626-5:2019(E)

Documents
Document Sharing Hub

© ISO 2019

Full document details: BS ISO 7626-5:2019

COPYRIGHT PROTECTED DOCUMENT

© ISO 2019

All rights reserved. Unless otherwise specified, or required in the context of its implementation, no part of this publication may be reproduced or utilized otherwise in any form or by any means, electronic or mechanical, including photocopying, or posting on the internet or an intranet, without prior written permission. Permission can be requested from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

© ISO 2019 – All rights reserved

Documents
Document Sharing Hub

Full document details: BS ISO 7626-5:2019

Contents

Page

Foreword ... **iv**

Introduction ... **v**

1 Scope ... **1**

2 Normative references ... **1**

3 Terms and definitions ... **1**

4 General characteristics of impact measurements ... **2**
- 4.1 General description ... 2
- 4.2 Advantages and limitations of impact excitation ... 3
  - 4.2.1 General ... 3
  - 4.2.2 Nonlinearity restrictions ... 4
  - 4.2.3 Signal-to-noise problems ... 4
  - 4.2.4 Limited frequency resolution ... 4
  - 4.2.5 Damping restrictions ... 4
  - 4.2.6 Dependence on operator skill ... 5

5 Support of the structure under test ... **5**
- 5.1 General ... 5
- 5.2 Ungrounded measurements ... 5
- 5.3 Grounded measurements ... 5

6 Application of the excitation ... **5**
- 6.1 Impactor design ... 5
- 6.2 Force spectrum characteristics ... 6
- 6.3 Control of the frequency range of excitation ... 10
- 6.4 Avoidance of impactor double hits ... 10

7 Transducer system ... **12**
- 7.1 General ... 12
- 7.2 Impactor calibration ... 12

8 Processing of the transducer signals ... **13**
- 8.1 Filtering ... 13
- 8.2 Transient capture characteristics ... 13
- 8.3 Sampling relationships ... 14
- 8.4 Avoidance of saturation (clipping) ... 15
- 8.5 Windowing techniques ... 15
  - 8.5.1 Force signal ... 15
  - 8.5.2 Windowing the response signals ... 19
- 8.6 Averaging techniques ... 23

9 Tests for validity of the measurements ... **24**
- 9.1 Coherence function ... 24
- 9.2 Repeatability check ... 25
- 9.3 Reciprocity check ... 25
- 9.4 Linearity check ... 25
- 9.5 Comparison with measurements using an attached exciter ... 25

Annex A (informative) **Correction of mobility measurements for the effects of exponential windowing** ... **26**

Bibliography ... **28**

© ISO 2019 – All rights reserved

Documents
Document Sharing Hub

Full document details: BS ISO 7626-5:2019

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*.

This second edition cancels and replaces the first edition (ISO 7626-5:1994), which has been technically revised.

The main changes compared with the previous edition are as follows:

— updating of normative and informative references in the bibliography;

— redrawing of figures and graphs.

A list of all parts in the ISO 7626 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

© ISO 2019 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 7626-5:2019

Introduction

0.1 General introduction to the ISO 7626 series on mobility measurement

Dynamic characteristics of structures assumed to behave linearly can be determined as a function of frequency from mobility measurements or measurements of the related frequency-response functions (FRF), 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 at the same or any other point. 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 velocity. In order to simplify the various parts of the ISO 7626 series, 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.

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, damping ratios and mode shapes);

c) predicting the dynamic interaction of interconnected structures;

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

e) determining the frequency dependent dynamic properties (i.e. the complex modulus of elasticity) of materials.

For some applications, a complete description of the dynamic characteristics can be required using measurements of forces and linear velocities along three mutually perpendicular axes as well as measurements of moments and rotational velocities 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 $6N \times 6N$.

NOTE 1 In general, the measurement directions do not need to be perpendicular to each other, but only their linear independence is needed.

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 linear response motions at key points on the structure. In other applications, only rotational mobilities can be of interest.

In order to simplify its use in the various mobility measurement tasks encountered in practice, ISO 7626 is published as a series comprising:

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

— ISO 7626-2, which covers mobility measurements using single-point linear excitation with an attached exciter.

— ISO 7626-5 (this document), which 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 linear or rotational velocity response to the phasor of the applied force or moment excitation. If the response is measured with an accelerometer, conversion to velocity is used to obtain the mobility.

© ISO 2019 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 7626-5:2019

Alternatively, the ratio of acceleration to force, known as accelerance, can be used to characterize a structure. In other cases, dynamic compliance, the ratio of displacement to force, can be used.

NOTE 2 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. However, this is misleading because the arithmetic reciprocal of mobility does not, in general, represent any of the elements of the impedance matrix of the structure. Mobility test data cannot be used directly as part of an analytic impedance model of the structure. To achieve compatibility of the data and the model, the impedance matrix of the model must be inverted to a mobility matrix, or vice versa. This point is elaborated upon in ISO 7626-1:2011, Annex A.

0.2 Introduction to this document

Impact excitation has become a popular method for measuring the frequency response of structures because of its inherent speed and relatively low cost to implement. However, the accuracy of mobility measurements made by using impact excitation is highly dependent upon both the characteristics of the test structure and the experimental techniques employed. With impact excitation, it can be difficult or impossible in certain cases to obtain the accuracy which is attainable using steady state or stationary excitation with an attached exciter, and the impact method carries an increased danger of gross measurement errors[6]. In spite of these limitations, impact testing can be an extremely useful excitation technique when applied properly.

This document provides a guide to the use of impact excitation for mobility measurements. Accurate mobility measurements always require careful attention to equipment selection and to the measurement techniques employed; these factors are especially important when using impact excitation. Furthermore, the characteristics of the test structure, especially its degree of nonlinearity, limit the accuracy which can be achieved. Subclause 4.2 describes these limitations on the use of impact excitation.

Because the exciter is not attached to the structure, this method makes it practical to measure a series of transfer mobilities of a structure by moving the excitation successively to each desired point on the structure, while the response motion transducer remains at a single fixed location and direction. Due to the principle of dynamic reciprocity, such measurements should be equal, assuming linearity, to the results obtained using an attached exciter at the same fixed location and direction with the response transducer relocated to each desired point on the structure. However, it can be difficult to impact the structure in all desired directions at certain locations, and in such cases, it can be more practical to use impact excitation at the fixed location and direction and relocate a multi-axis response transducer to the desired response locations.

NOTE 1 When a multi-axis transducer is used at a fixed location for a modal test and if the impact is applied in one direction of the transducer at each point, then only the mode shape components in that direction are obtained.

NOTE 2 The mass of the multiaxial transducer can change the mass properties of the structure leading to an inconsistent set of measured transfer functions. This can cause serious problems in using the FRFs for experimental modal analysis.

© ISO 2019 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 7626-5:2019

Mechanical vibration and shock — Experimental determination of mechanical mobility —

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

1 Scope

This document specifies procedures for measuring mechanical mobility and other frequency-response functions of structures excited by means of an impulsive force generated by an exciter which is not attached to the structure under test.

It is applicable to the measurement of mobility, accelerance or dynamic compliance, either as a driving point measurement or as a transfer measurement, using impact excitation. Other excitation methods, such as step relaxation and transient random, lead to signal-processing requirements similar to those of impact data. However, such methods are outside the scope of this document because they involve the use of an exciter which is attached to the structure.

The signal analysis methods covered are all based on the discrete Fourier transform (DFT), which is performed mostly by a fast Fourier transform (FFT) algorithm. This restriction in scope is based solely on the wide availability of equipment which implements these methods and on the large base of experience in using these methods. It is not intended to exclude the use of other methods currently under development.

Impact excitation is also widely used to obtain uncalibrated frequency-response information. For example, a quick impact test which obtains approximate natural frequencies and mode shapes can be quite helpful in planning a random or sinusoidal test for accurate mobility measurements. These uses of impact excitation to obtain qualitative results can be a first stage for mobility measurements.

This document is limited to the use of impact excitation techniques for making accurate mobility measurements.

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*

3 Terms and definitions

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

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

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

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

© ISO 2019 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 7626-5:2019

3.1
frequency-response function
FRF
frequency-dependent ratio of Fourier transform of the motion-response of a linear system to the one of the excitation force

Note 1 to entry: Frequency-response functions are properties of linear dynamic systems which do not depend on the type of excitation function. Excitation may be harmonic, random or transient functions of time. The test results obtained with one type of excitation may thus be used for predicting the response of the linear system to any other type of excitation.

Note 2 to entry: Linearity of the system is a condition which, in practice, may be met only approximately, depending on the type of system and on the magnitude of the input. Care has to be taken to avoid nonlinear effects, particularly when applying impulse excitation. Structures which are known to be nonlinear (for example, certain riveted structures) should not be tested with impulse excitation and great care is required when using random excitation for testing such structures.

Note 3 to entry: Motion may be expressed in terms of either displacement, velocity or acceleration; the corresponding frequency-response function designations are dynamic compliance, mobility and accelerance or dynamic stiffness, impedance, and effective mass, respectively.

Note 4 to entry: In practice, the discrete Fourier transform (DFT) by the fast Fourier transform (FFT) is used as an approximation of the continuous Fourier transform. The errors of this approximation can be reduced to levels below those of other measurement errors. Hence, the use of the DFT does not necessarily limit the accuracy of the measurement.

3.2
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

3.3
power spectral density
square of absolute value of the FFT of a signal multiplied by $2/T$ where T is the length of the time signal, meaning mean-square value of a time signal per unit bandwidth

3.4
energy spectral density
power spectral density (3.3) multiplied by the length of the record in seconds, which is used in the spectral calculation of a transient signal

Note 1 to entry: This definition assumes that the transient signal is entirely contained within the record.

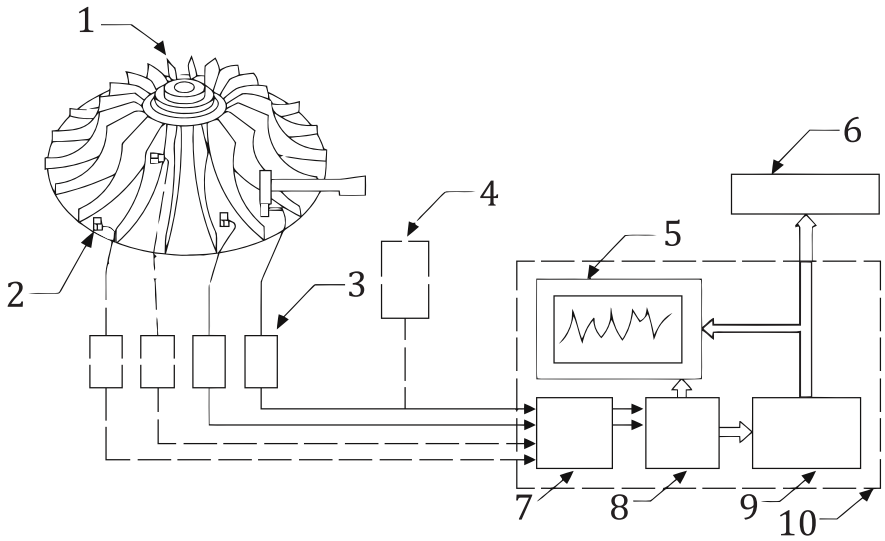
4 General characteristics of impact measurements

4.1 General description

The instrumentation required for mobility measurements using impact excitation consists of an impact hammer with built-in force transducer, one or more motion-response transducers with their associated signal conditioners and a digital Fourier transform analysis system or analyser having at least two simultaneous input channels. The instrumentation system is shown schematically in Figure 1. This document provides information on the selection and use of these components.

The force and response signals from each impact are anti-aliasing filtered and then digitally sampled using the pre-triggering or transient capture mode of the analyser. Each of the resulting digital records should represent a single impact event. The discrete Fourier transform of each record is computed by the analyser. Frequency domain averaging of several frequency-response functions obtained from impacts at a given point may be performed to improve the estimate.

© ISO 2019 – All rights reserved
Documents
Document Sharing Hub
Full document details: BS ISO 7626-5:2019



Key

1 structure under test
2 motion-response transducer(s)
3 signal conditioners
4 storage oscilloscope
5 display
6 output device (printer/plotter)
7 amplifiers and analogue anti-aliasing filter
8 analogue/digital converter
9 DFT/FFT and FRF computation
10 signal analyser

_____ basic feature
-------- optional feature
DFT discrete Fourier transform
FFT fast Fourier transform
FRF frequency response function

Figure 1 — Instrumentation block diagram for impact excitation

4.2 Advantages and limitations of impact excitation

4.2.1 General

Impact excitation offers the following intrinsic advantages compared with the use of an attached exciter:

a) measurement speed;

b) ease of installation;

c) ease of relocating the excitation point;

d) no change of structure, which can be caused by the exciter attachment method (see ISO 7626-2).

On the other hand, the following limitations of impact excitation shall be taken into account:

a) nonlinearity restrictions;

b) signal-to-noise problems;

c) limited frequency resolution;

d) damping restrictions;

© ISO 2019 – All rights reserved

Documents
Document Sharing Hub
Full document details: BS ISO 7626-5:2019

e) dependence on operator skill.

These limitations are discussed in 4.2.2 to 4.2.6.

4.2.2 Nonlinearity restrictions

Mobility measurements on structures which exhibit a significant degree of nonlinearity always demand special precautions. In such cases, the use of sinusoidal or random excitation with an attached exciter is preferred, if practical, instead of the impact-excitation technique.

With the impact-excitation technique, the energy needed to drive the response signal to a certain magnitude is put into the structure during a limited part of the time period used for analysis. Compared with sinusoidal or random excitation, the force of the impact pulse therefore can be much larger and the effects of nonlinearity are thus likely to be increased.

For measurements on systems with a significant degree of nonlinearity, it is very important to keep a level of the force used for the excitation or a level of the system response. In this aspect, the sinusoidal excitation techniques are preferable. If a hand-held hammer is used to generate the impacts, the individual force amplitudes can vary significantly. The repeatability of such a measurement can be poor for nonlinear systems.

4.2.3 Signal-to-noise problems

Because the average signal levels are low compared with the peak levels, impact measurements require a very low noise testing environment and the maximum possible dynamic range in the measurement system. This requirement can rule out the use of current analogue tape-recording techniques.

A significant noise problem can occur because the force signal duration is short compared with the total record length. This situation can result in the instrumentation electrical noise and the mechanically induced background noise having a mean square value that is significant compared with the mean square value of the input force. Such noise can be reduced by the windowing techniques described in 8.5.

4.2.4 Limited frequency resolution

The frequency increment, in hertz, which results from a discrete Fourier transform (including the case of a band-limited or “zoom” analysis), is equal to the reciprocal of the record length, in seconds. Because each record represents a single impact event, the record length is effectively limited to the time required for the impulse response of the structure to decay to the level of the background noise. Therefore, the frequency resolution attainable depends on both the response of the structure and the background noise level. In some cases, it can be impractical (and unnecessary) using impact excitation to achieve directly the frequency resolution specified in ISO 7626-2; however, accurate mobility values can be obtained at discrete frequencies with sufficiently fine resolution for most applications. If the test structure exhibits high modal density (i.e. multiple resonances within a narrow frequency band), it can be difficult to achieve sufficiently fine resolution for an accurate mobility measurement. In those cases, one of the steady-state excitation methods with “zoom” analysis is preferred.

By its very nature, the spectrum of an impact extends from DC to some upper frequency limit (see Clause 6). This inability to band limit the excitation spectrum restricts the usefulness of “zoom” analysis for improving the frequency resolution of impact measurements, and the impact places further demands on the dynamic range of the measurement system. It also increases the danger of undetected overloads (clipping) in the measurement system due to high-amplitude out-of-band signals. See 6.3 and 8.4. The time resolution has to be high enough for the impact signal to be recorded at a sufficient number of sampling points. However, a higher time resolution can decrease the frequency resolution when the number of data points for the FFT is fixed.

4.2.5 Damping restrictions

Impact excitation has limitations for testing heavily damped structures because the short duration of the response signal leads to a trade-off between frequency resolution and background noise level.

© ISO 2019 – All rights reserved
AVA Documents Document Sharing Hub
Full document details: BS ISO 7626-5:2019