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Standards Secretariat
Acoustical Society of America
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AMERICAN NATIONAL STANDARD
Methods for the Experimental Determination of Mechanical Mobility. Part I: Basic Definitions and Transducers

ABSTRACT

This standard is the first part of a series of five standards covering the experimental determination of mechanical mobility of structures by a variety of methods appropriate for different test situations. The present Part I of this series covers basic concepts and definitions and serves as a guide for the selection, calibration, and evaluation of the transducers and instruments used in mobility measurements. The material in Part I is common to most mobility measurement tasks. This document supersedes ANSI Standard S2.6-1963(R1976).

The future parts of this series will cover specific mobility measurement situations such as the use of steady-state rectilinear excitation, steady-state torsional excitation, measurements of the entire mobility matrix using steady-state excitation, and mobility measurements using impact excitation, as well as other forcing functions which use Fourier transform techniques for data reduction.

The present document (Part I of this series) has four appendices containing selected references to the literature, a discussion of the relationships between mechanical mobility and impedance, a discussion of mobility as a frequency response function, and conversion factors from SI to conventional English units as applicable to mobility and related ratios.

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FOREWORD

[This Foreword is not a part of American National Standard Methods for the Experimental Determination of Mechanical Mobility. Part I: Basic Definitions and Transducers, S2.31-1979.]

This standard has been developed under the jurisdiction of American National Standards Committee S2 using the American National Standards Institute (ANSI) Standards Committee Procedure. The Acoustical Society of America holds the Secretariat for Committee S2. This standard has been approved for publication by ANSI and by the Acoustical Society of America Committee on Standards (ASACOS).

The scope of Standards Committee S2 on Mechanical Shock and Vibration, under whose jurisdiction this standard was prepared, is as follows:

> Standards, specifications, methods of measurement and test, and terminology in the fields of mechanical shock and vibration, but excluding those aspects which pertain to biological safety, tolerance, and comfort.

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Suggestions for improvement of this standard will be welcomed. They should be sent to the Standards Secretariat, Accoustical Society of America, 335 East 45th Street, New York, NY 10017.

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INTRODUCTION

The dynamic characteristics of structures can be determined from measurements of mobility or of the related frequency response functions called accelerance and dynamic compliance. These frequency response functions describe the relationship of the motion response (output) of a structure to a force input as a function of frequency. This response ratio has a magnitude equal to the ratio of the output to the input amplitudes and a phase equal to the phase of the output relative to the input. Traditionally, the input force in mobility measurements has been sinusoidal, but recent advances in technology have made it possible to use random or transient forcing functions as described in detail in Appendix C.

Mobility measurements are usually made with force transducers and accelerometers within the frequency range of 5–5000 Hz, although special applications may require other frequency ranges and/or other types of transducers.

Mobility measurements are used for:

(1) Predicting the dynamic response of structures to arbitrary input forces,

(2) Determining structural resonance modes (natural frequencies, mode shapes, and damping ratios),

(3) Determining the dynamic interaction of interconnected structures and equipment, and

(4) Determining dynamic properties of materials or composites (complex modulus of elasticity).

The *complete* determination of the dynamic characteristics of some structures may require the measurement of rectilinear forces and motions as well as the measurement of moments and rotational motions about three mutually perpendicular axes. The measurement of the 21 independent[a] terms, each a function of frequency, yields a 6×6 mobility matrix at each point of interest. This is further complicated by the fact that each of the N points of interest in a structure has a 6×6 mobility matrix. Thus, the system has an overall matrix of size $6N \times 6N$. There are $36N^2$ elements in all of which $(18N^2 + 3N)$ need to be measured. Much less detail is usually required for practical applications. Often, it is sufficient to measure the driving point mobility and the transfer mobilities determined from the application of a single force in one direction and the measurement of rectilinear motions in the same or other directions at the same point or other points on the structure. For example, one or two such forcing positions may provide sufficient information to determine specific modal parameters of the structure. An alternative to the use of a single driving point and multiple response points is sometimes more practical when an impact method is used to apply the input force. This alternative involves the application of forces, one at a time, at all the points and directions of interest and measuring the rectilinear response motion at a single point and single direction for each of the force applications.

In order to simplify the use of this standard in performing the varied mobility measurement tasks encountered in practice, this standard will be issued in five separate parts:

Part I (the present document) covers basic definitions and transducers. This material is common to most mobility measurement tasks.

Part II will cover mobility measurements using steady-state translational excitation at a single point.

Part III will cover mobility measurements using steady-state rotational excitation at a single point. This is primarily intended for rotor torsional resonance predictions.

Part IV will cover mobility measurements of the entire mobility matrix using steady-state excitation.

Part V will cover mobility measurements using impact excitation as well as other forcing functions which use Fourier transform techniques for data reduction.

Mechanical mobility is defined as the ratio of the phasor of the velocity to the phasor of the applied force.[b] More detailed definitions of mechanical mobility and other measures of the dynamic characteristics of structures are given in Sec. 2 of this standard. The motion measurements are usually made with accelero-

[a] Mobility matrices are usually symmetric, at least for linear, bilateral networks.

[b] Henceforth, the shorter terms "velocity phasor" and "force phasor" will be used for the phasors of the velocity and force. The definition of these phasors is given in Appendix C.

meters. Acceleration data must be converted to velocity if it is desired to obtain the mechanical mobility of the system being measured. Alternatively, the ratio of acceleration to force, called accelerance,[c] may be used to characterize a structure. In still other cases, dynamic compliance, the ratio of the displacement phasor to the input force phasor, is used to characterize a structure.

Historically, mobility type data have often been expressed in terms of the *reciprocal* of one of the above dynamic characteristics. The arithmetic reciprocals (as opposed to matrix inverse) of mechanical accelerance, mobility, and compliance are called effective mass, *free* mechanical impedance, and *free* dynamic stiffness, respectively. However, these reciprocal characteristics are, in general, not directly compatible with the analytical methods used to describe the dynamic characteristics of a physical system.[1] (Superscript numerals in text indicate references listed in Appendix A of this standard.) If the test data are to be used as part of an analytical model of a system, compatibility must be assured. This could be done, for instance, by measuring the *blocked* mechanical impedances or by measuring all significant terms of the mobility matrix and inverting this matrix. This is elaborated upon in Appendix B.

In this standard, the phrase "mobility measurement" will be used in a general way which includes the measurement of mobility, accelerance, and dynamic compliance, since these differ only in the type of signals used to compute the mobility type function.

Before carrying out mobility measurements it is necessary to evaluate the characteristics of the force transducers and the accelerometers to be used in order to ensure that accurate amplitude and phase information can be obtained over the entire frequency range of interest.

This standard is a guide for the selection, calibration, and evaluation of the transducers and instruments for their suitability in making mobility measurements.

1 PURPOSE AND SCOPE

1.1 Purpose

This document provides basic definitions with comments and identifies the calibration tests, environmental tests, and physical measuremments necessary to determine the suitability of impedance heads[d], force transducers, and accelerometers for use in measuring mechanical mobility.

1.2 Scope

This document is limited to information which is basic to various types of driving point and transfer mobility, accelerance, and dynamic compliance measurements.

1.3 Related standards

This standard is coordinated with the following existing standards which are closely related to mobility measurements:

American National Standard Acoustical Terminology Including Mechanical Shock and Vibration, S1.1-1960.

American National Standard Methods for the Calibration of Shock and Vibration Pickups, S2.2-1959.

American National Standard for the Selection of Calibrations and Tests for Electrical Transducers Used for Measuring Shock and Vibration, S2.11-1969.

American National Standard Symbols for Mechanical and Acoustical Elements as Used in Schematic Diagrams, Y32.18-1972.

Instrument Society of America, Guide for Specification and Test of Piezoelectric Acceleration Transducers for Aerospace Testing, RP37.2-1964.

International Organization for Standardization, Vibration and Shock-Vocabulary, ISO 2041, 1975.

2 DEFINITIONS

The definitions of terms used in this standard are found in ANSI Standards S1.1, as well as in ISO Standards ISO 2041. Several of the more important definitions used in the measurement and presentation of mechanical mobility data are listed below to emphasize their use in this standard.

[c]This term has often been called inertance, but the use of inertance is discouraged.

[d]Traditionally, assemblies of force transducers and accelerometers have been termed impedance heads. These devices are used to measure the force and motion parameters from which the mechanical mobility is determined.