INTERNATIONAL STANDARD

ISO 2041

Fourth edition
2018-10

Mechanical vibration, shock and condition monitoring — Vocabulary

Vibrations et chocs mécaniques, et leur surveillance — Vocabulaire

Reference number
ISO 2041:2018(E)

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Published in Switzerland

Contents

Page

Foreword

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

This fourth edition cancels and replaces the third edition (ISO 2041:2009), which has been technically revised.

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

— changes in format to conform to the ISO/IEC Directives, Part 2: 2018;

— correction of the formula in 3.1.58 (2.1.58 in the previous edition);

— addition of Figure 4 and Figure 5.

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.

Mechanical vibration, shock and condition monitoring — Vocabulary

1 Scope

This document defines terms and expressions unique to the areas of mechanical vibration, shock and condition monitoring.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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/

3.1 General terms

3.1.1
displacement
relative displacement
⟨vibration and shock⟩ time varying quantity that specifies the change in position of a point on a body with respect to a reference frame

Note 1 to entry: The reference frame is usually a set of axes within which a set of coordinates defines the change in position of a point on a body. In general, a rotation displacement vector, a translation displacement vector, or both can represent the displacement.

Note 2 to entry: A displacement is designated as a relative displacement if it is measured with respect to a reference frame other than the primary reference frame designated in a given case.

Note 3 to entry: Displacement can be:

— oscillatory, in which case simple harmonic components can be defined by the displacement amplitude (and frequency), or

— random, in which case the root-mean-square (rms) displacement (and band-width and probability density distribution) can be used to define the probability that the displacement will have values within any given range.

Note 4 to entry: Displacements of short time are defined as transient displacements. Non-oscillatory displacements are defined as sustained displacements, if of long duration, or as displacement pulses, if of short duration.

3.1.2
velocity
relative velocity
⟨vibration and shock⟩ rate of change of displacement

Note 1 to entry: In general, velocity is time-dependent.

Note 2 to entry: The reference frame is usually a set of axes within which a set of coordinates defines the rate of change of displacement of a point on a body. In general, a rotation velocity vector, a translation velocity vector, or both can represent the velocity.

Note 3 to entry: A velocity is designated as a relative velocity if it is measured with respect to a reference frame other than the primary reference frame designated in a given case. The relative velocity between two points is the vector difference between the velocities of the two points.

Note 4 to entry: Velocity can be:

— oscillatory, in which case simple harmonic components can be defined by the velocity amplitude (and frequency), or

— random, in which case the root-mean-square (rms) velocity (and band-width and probability density distribution) can be used to define the probability that the velocity will have values within any given range.

Note 5 to entry: Velocities of short time duration are defined as transient velocities. Non-oscillatory velocities are defined as sustained velocities, if of long duration.

3.1.3
acceleration
relative acceleration
⟨vibration and shock⟩ rate of change of velocity

Note 1 to entry: In general, acceleration is time-dependent.

Note 2 to entry: The reference frame is usually a set of axes within which a set of coordinates defines the rate of change of velocity of a point on a body. In general, a rotation acceleration vector, a translation acceleration vector, or both and the Coriolis acceleration can represent the acceleration.

Note 3 to entry: An acceleration is designated as a relative acceleration if it is measured with respect to a reference frame other than the inertial reference frame designated in a given case. The relative acceleration between two points is the vector difference between the accelerations of the two points.

Note 4 to entry: In the case of time-dependent accelerations, various self-explanatory modifiers, such as peak, average and rms (root-mean-square), are often used. The time intervals over which the average or root-mean-square values are taken should be indicated or implied.

Note 5 to entry: Acceleration can be:

— oscillatory, in which case simple harmonic components can be defined by the acceleration amplitude (and frequency), or

— random, in which case the rms acceleration (and band-width and probability density distribution) can be used to define the probability that the acceleration will have values within any given range.

Note 6 to entry: Accelerations of short time duration are defined as transient accelerations. Non-oscillatory accelerations are defined as sustained accelerations, if of long duration, or as acceleration pulses, if of short duration.

3.1.4
standard acceleration due to gravity
g_n
standard acceleration of free fall
unit, 9,806 65 metres per second-squared (9,806 65 m/s^2)

Note 1 to entry: The value was adopted in the International Service of Weights and Measures in 1901 (Resolution of the 3rd CGPM) as the standard for acceleration due to gravity.

Note 2 to entry: This "standard value" (g_n = 9,806 65 m/s^2 = 980,665 cm/s^2 approximately 386,089 in/s^2 approximately 32,174 0 ft/s^2) should be used for reduction to standard gravity of measurements made in any location on Earth.

Note 3 to entry: Frequently, the magnitude of acceleration is expressed in units of g_n.

Note 4 to entry: The actual acceleration produced by the force of gravity at or below the surface of the Earth varies with the latitude and elevation of the point of observation. This variable is often expressed using the symbol g. Caution should be exercised if this is done so as not to create an ambiguity with this use and the standard symbol for the unit of the gram.

Note 5 to entry: Historically, this value of g_n was the conventional reference for calculating the now obsolete unit kilogram force.

3.1.5
force
dynamic influence that changes a body from a state of rest to one of motion or changes its velocity

Note 1 to entry: A force could also change a body's size or shape if the body resists motion.

Note 2 to entry: Force is expressed in newtons. One newton is the force required to give a mass of one kilogram an acceleration of one metre per second squared.

3.1.6
restoring force
reactive force caused by the elastic property of a structure when it is being deformed

3.1.7
jerk
rate of change of acceleration

3.1.8
inertial reference system
inertial reference frame
coordinate system or frame which is fixed in space or moves at a constant velocity without rotational motion and thus, not accelerating

3.1.9
inertial force
reactive force exerted by a mass when it is being accelerated

3.1.10
oscillation
variation, usually with time, of the magnitude of a quantity with respect to a specified reference when the magnitude is alternately greater and smaller than the specified reference

Note 1 to entry: See *vibration* (3.2.1).

Note 2 to entry: Variations with time such as shock processes or creeping motions are also considered to be oscillations in a more general sense of the word.

3.1.11
environment
all external conditions influencing a system at any given moment

Note 1 to entry: See *induced environment* (3.1.12) and *natural environment* (3.1.13).

3.1.12
induced environment
conditions external to a system generated as a result of the operation of the system

3.1.13
natural environment
conditions generated by the forces of nature and the effects of which are experienced by a system when it is at rest as well as when it is in operation

3.1.14
preconditioning
climatic and/or mechanical and/or electrical treatment procedure which may be specified for a particular system so that it attains a defined state

3.1.15
conditioning
climatic and/or mechanical and/or electrical conditions to which a system is subjected in order to determine the effect of such conditions upon it

3.1.16
excitation
stimulus
external force (or other input) applied to a system that causes the system to respond in some way

3.1.17
response
<system> output quantity of a system

3.1.18
transmissibility
tranmissibility function
dimensionless complex ratio of the response of a system in forced vibration to the excitation

Note 1 to entry: The ratio may be one of forces, displacements, velocities or accelerations.

3.1.19
overshoot
maximum transient response that exceeds the desired response

Note 1 to entry: If the output of a system is changed from a steady value A to a steady value B by varying the input, such that B is greater than A, the response is said to overshoot when the maximum transient response exceeds the value B.

Note 2 to entry: The difference between the maximum transient response and the value B is the value of the overshoot. This is usually expressed as a percentage.

3.1.20
undershoot
minimum transient response that falls below the desired response

Note 1 to entry: If the output of a system is changed from a steady value A to a steady value B by varying the input, such that B is less than A, the response is said to undershoot when the minimum transient response is less than the value B.

Note 2 to entry: The difference between the minimum transient response and the value B is the value of the undershoot. This is usually expressed as a percentage.

3.1.21
system
set of interrelated elements considered in a defined context as a whole and separated from their environment

3.1.22
linear system
system in which the magnitude of the response is proportional to the magnitude of the excitation

Note 1 to entry: This definition implies that the principle of superposition can be applied to the relationship between the output response and the input excitation.

3.1.23
mechanical system
system comprising elements of mass, stiffness and damping

3.1.24
foundation
structure that supports a mechanical system

Note 1 to entry: It can be fixed in a specified reference frame or it can undergo a motion.

3.1.25
seismic system
system consisting of a mechanical system attached to a reference base by one or more flexible elements, with damping normally included

Note 1 to entry: Seismic systems are usually idealized as single-degree-of-freedom systems with linear (viscous) damping.

Note 2 to entry: The natural frequencies of the mass as supported by the flexible elements are relatively low for seismic systems associated with displacement or velocity transducers, and are relatively high for acceleration transducers, as compared with the range of frequencies to be measured.

Note 3 to entry: When the natural frequency of the seismic system is low relative to the frequency range of interest, the mass of the seismic system may be considered to be at rest over this range of frequencies.

3.1.26
equivalent system

system that can be substituted for another system for the purpose of analysis

Note 1 to entry: Many types of equivalence are common in vibration and shock technology:

a) a torsional system equivalent to a translational system;

b) an electrical or acoustical system equivalent to a mechanical system, etc.;

c) equivalent stiffness;

d) equivalent damping.

3.1.27
degrees of freedom
DOF
minimum number of generalized coordinates required to define completely the configuration of a mechanical system

Note 1 to entry: This applies to mechanical systems, not to be confused with statistical degrees of freedom.

3.1.28
discrete system
lumped parameter system
mechanical system in which the mass, stiffness and/or damping elements are discretely located

3.1.29
single-degree-of-freedom system
SDOF
system requiring only one coordinate to define completely its configuration at any instant

3.1.30
multi-degree-of-freedom system
system for which two or more coordinates are required to define completely the configuration of the system at any instant

3.1.31
continuous system
mechanical system in which the mass, stiffness and/or damping properties are spatially distributed rather than discretely located

Note 1 to entry: The configuration of a continuous system is specified by a function of a continuous spatial variable, or variables, in contrast to a discrete or lumped parameter system that requires only a finite number of coordinates to specify its configuration.

3.1.32
centre of gravity
point through which the resultant of the weights of the component particles of a body passes without resulting in a moment given any orientation of that body with respect to a gravitational field

Note 1 to entry: If the field is uniform, the centre of gravity coincides with the *centre of mass* (3.1.33).

3.1.33
centre of mass
point of a body with reference to a Cartesian coordinate system where the first moment of the overall mass is equal to the first moments of mass of all points of that body

Note 1 to entry: This is the point at which an object is in balance in a uniform gravitational field.

3.1.34
principal axes of inertia
three mutually perpendicular axes intersecting each other at a given point about which the products of inertia of a solid body are zero

Note 1 to entry: If the point is the centre of mass of the body, the axes and moments are called central principal axes and central principal moments of inertia.

Note 2 to entry: In balancing, the term “principal inertia axis” is used to designate the one central principal axis (of the three such axes) most nearly coincident with the shaft axis of the rotor and is sometimes referred to as the balance axis or the mass axis.

3.1.35
moment of inertia
sum (integral) of the product of the masses of the individual particles (elements of mass) of a body and the square of their perpendicular distances from the axis of rotation

3.1.36
product of inertia
sum (integral) of the product of the masses of the individual particles (elements of mass) of a body and their distances from two mutually perpendicular planes

3.1.37
stiffness
ratio of change of force (or torque) to the corresponding change in translational (or rotational) deformation of an elastic element

Note 1 to entry: See also *dynamic stiffness* (3.1.58).

3.1.38
compliance
reciprocal of stiffness

Note 1 to entry: See also *dynamic compliance* (3.1.57).

3.1.39
neutral surface
neutral surface of a beam in simple flexure
surface in which there is no strain

Note 1 to entry: It should be stated whether or not the neutral surface is a result of the flexure alone, or whether it is a result of the flexure and other superimposed loads.

3.1.40
neutral axis
neutral axis of a beam in simple flexure
line or plane in a beam where the longitudinal stress, tensile or compressive is zero

3.1.41
transfer function
mathematical representation of the relationship between the input and output of a linear time-invariant system

Note 1 to entry: A transfer function is usually a complex function defined as the ratio of the Laplace transforms of the output to the input of a linear time-invariant system.

Note 2 to entry: It is usually given as a function of frequency, and is usually a complex function. See *response* (3.1.17), *transmissibility* (3.1.18) and *transfer impedance* (3.1.50).

3.1.42
complex excitation
excitation expressed as a complex quantity with amplitude and phase angle

Note 1 to entry: The concepts of complex excitations and responses were evolved historically in order to simplify calculations. The actual excitation and response are the real parts of the complex excitation and response. If the system is linear, the concept is valid because superposition holds in such a situation.

Note 2 to entry: This term should not be confused with excitation by a complex vibration, or vibration of complex waveform. The use of the term “complex vibration” in this sense is deprecated.

3.1.43
complex response
response of a system expressed as a complex quantity with amplitude and phase angle from a specified excitation

Note 1 to entry: See the notes under *complex excitation* (3.1.42).

3.1.44
modal analysis
vibration analysis method that characterizes a complicated, linear system by its modes of vibration, i.e. natural frequencies, modal damping and mode shapes

3.1.45
modal matrix
linear transformation matrix which consists of the eigen vectors or modal vectors of a system

Note 1 to entry: It renders the system both inertially and elastically uncoupled, i.e. the modal mass and modal stiffness matrices are transformed into diagonal matrices.

3.1.46
modal stiffness
stiffness element associated with a specified mode of vibration

3.1.47
modal density
number of modes with respect to a given bandwidth

Note 1 to entry: Modal density is a measure widely used in structural dynamics as a diagnostic tool in assessing vibration power flow in complex, structural systems. It can play a crucial role in determining changes in vibration power flow that may be a precursor to fatigue failure in some part of the structure, or a metric used in structural condition monitoring evaluations. In addition to these applications, it is a parameter required by the Statistical Energy Analysis method for evaluating the high-frequency response of complex structures and in selecting appropriate vibration-control methods and devices.

3.1.48
mechanical impedance
complex ratio of force to velocity at a specified point and degree-of-freedom in a mechanical system

Note 1 to entry: The force and velocity may be taken at the same or different points and degrees-of-freedom in the system undergoing simple harmonic motion.

Note 2 to entry: In the case of torsional mechanical impedance, the terms “force” and “velocity” should be replaced by “torque” and “angular velocity”, respectively.

Note 3 to entry: In general, the term “impedance” applies to linear systems only.

Note 4 to entry: The concept is extended to nonlinear systems where the term “incremental impedance” is used to describe a similar quantity.

3.1.49
direct mechanical impedance
driving point mechanical impedance

complex ratio of the force to velocity taken at the same point or degree-of-freedom in a mechanical system during simple harmonic motion

Note 1 to entry: See the notes under *mechanical impedance* (3.1.48).

3.1.50
transfer impedance
transfer mechanical impedance
complex ratio of the force applied at point *i*, in a specified degree-of-freedom in a mechanical system, to the velocity at another point *j* in a specified direction or degree-of-freedom in the same system, during simple harmonic motion

Note 1 to entry: See the notes under *mechanical impedance* (3.1.48).

3.1.51
free impedance
ratio of the applied excitation complex force to the resulting complex velocity with all other connection points of the system free, i.e. having zero restraining forces

Note 1 to entry: Historically, often no distinction has been made between blocked impedance and free impedance. Caution should, therefore, be exercised in interpreting published data.

Note 2 to entry: Free impedance is the arithmetic reciprocal of a single element of the mobility matrix. While experimentally determined free impedances could be assembled into a matrix, this matrix would be quite different from the blocked impedance matrix resulting from mathematical modelling of the structure and, therefore, would not conform to the requirements for using mechanical impedance in an overall theoretical analysis of the system.

3.1.52
blocked impedance
impedance at the input when all output degrees of freedom are connected to a load of infinite mechanical impedance

Note 1 to entry: Blocked impedance is the frequency-response function formed by the ratio of the phasor of the blocking or driving-point force response at point *i*, to the phasor of the applied excitation velocity at point *j*, with all other measurement points on the structure "blocked", i.e. constrained to have zero velocity. All forces and moments required to fully constrain all points of interest on the structure need to be measured in order to obtain a valid blocked impedance matrix.

Note 2 to entry: Any changes in the number of measurement points or their location will change the blocked impedances at all measurement points.

Note 3 to entry: The primary usefulness of blocked impedance is in the mathematical modelling of a structure using lumped mass, stiffness and damping elements or finite element techniques. When combining or comparing such mathematical models with experimental mobility data, it is necessary to convert the analytical blocked impedance matrix into a mobility matrix or vice versa.

3.1.53
frequency-response function
FRF
frequency-dependent ratio of the motion-response Fourier transform to the Fourier transform of the excitation force of a linear system

Note 1 to entry: Excitation can be harmonic, 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.

Note 2 to entry: Motion may be expressed in terms of velocity, acceleration or displacement; the corresponding frequency-response function designations are mobility, accelerance and dynamic compliance or impedance, effective (i.e. apparent) mass and dynamic stiffness, respectively (see Table 1).

3.1.54
mobility
mechanical mobility
complex ratio of the velocity, taken at a point in a mechanical system, to the force, taken at the same or another point in the system

Note 1 to entry: Mobility is the ratio of the complex velocity-response at point *i* to the complex excitation force at point *j* 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.

Note 2 to entry: The term "point" designates both a location and a direction.

Note 3 to entry: The velocity response can be either translational or rotational, and the excitation force can be either a rectilinear force or a moment.

Note 4 to entry: If the velocity response measured is a translational one and if the excitation force applied is a rectilinear one, the units of the mobility term will be m/(N·s).

Note 5 to entry: Mechanical mobility is the matrix inverse of mechanical impedance.

3.1.55
direct mobility
direct mechanical mobility
driving point mobility
driving point mechanical mobility
complex ratio of velocity and force taken at the same point in a mechanical system

Note 1 to entry: Driving-point mobility is the frequency-response function formed by the ratio, in metres per newton second, of the velocity-response complex amplitude at point *j* to the excitation force complex amplitude 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.

3.1.56
transfer mobility
transfer mechanical mobility
mechanical mobility where the velocity and the force are considered at different points of the system

3.1.57
dynamic compliance
frequency-dependent ratio of the spectrum, or spectral density, of the displacement to the spectrum, or spectral density, of the force

3.1.58
dynamic stiffness
dynamic elastic constant
dynamic spring constant
complex ratio of the force, taken at a point in a mechanical system, to the displacement, taken at the same or another point in the system

Note 1 to entry: The dynamic stiffness may be dependent upon the strain (amplitude and frequency), strain-rate, temperature or other conditions.

Note 2 to entry: The complex dynamic stiffness, k^*, of a linear translational single-degree-of-freedom system characterized by the equation

$$m\frac{\mathrm{d}^2x}{\mathrm{d}t^2}+c\frac{\mathrm{d}x}{\mathrm{d}t}+kx=F$$

where $F = F_0\,\mathrm{e}^{\mathrm{i}\omega t}$ and $x = x_0\mathrm{e}^{\mathrm{i}\omega t}$

is equal to

$$k* = \frac{F_0}{x_0} = k - m\omega^2 + \mathrm{i}\omega c = k\left\{1-\left(\frac{\omega}{\omega_0}\right)^2 + 2\mathrm{i}\varsigma\left(\frac{\omega}{\omega_0}\right)\right\}$$

where

c	is the linear (viscous) damping coefficient;
e	is the base of natural logarithms;
F_0	is the force amplitude;
i	$=\sqrt{-1}$;
k	is the elastic (spring) constant;
m	is the mass;

t	is the time;
x	is the displacement;
x_0	is the displacement amplitude;
$\zeta \left(= \frac{c}{2\sqrt{mk}} \right)$	is the damping ratio;
ω	is the angular frequency;
$\omega_0 \left(= \sqrt{k / m} \right)$	is the natural angular frequency.