INTERNATIONAL STANDARD

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Second edition
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Mechanical vibration and shock — Mechanical impedance of the human hand-arm system at the driving point

Vibrations et chocs mécaniques — Impédance mécanique du système main-bras au point d'entrée

Reference number
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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 10068 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 4, *Human exposure to mechanical vibration and shock*.

This second edition cancels and replaces the first edition (ISO 10068:1998), of which it constitutes a technical revision. The second edition includes the results of measurements of hand-arm impedance conducted since publication of the first edition, and it includes new models for apparent mass and mechanical impedance. The models now possess anatomic compatibility, and identify components for the fingers, palm, wrist and arm, and upper body. A model of the hand-arm system is provided when a glove is worn to estimate the transmissibility of vibration from a vibrating handle to the surface of the hand. The frequency dependency of the vibration power absorbed by the hand-arm system and by structures within the hand-arm system (i.e. fingers, palm and wrist, and arm) is also included. Information on methods for measuring the mechanical impedance of the hand-arm system is also provided in an annex.

Introduction

The mechanical impedance of the human hand-arm system at the driving point provides a measure of the overall biodynamic properties of the hand-arm system in specified conditions. When the hands are coupled to a vibrating tool or machine, the dynamic behaviour of the tool or machine could be affected by the biodynamic properties of the hand-arm system. Therefore, the mechanical impedance can be used to help design or develop:

a) power tools, and tool handles;

b) vibration-reducing and protective devices;

c) testing apparatus with which to measure the handle vibration of power tools.

Values of the mechanical impedance can be used to establish mechanical-equivalent models of the hand-arm system. The models can be used to analyse the vibration of tools and anti-vibration devices, and to guide the construction of testing apparatus. The models can also be used to estimate biodynamic responses such as vibration power absorption and biodynamic forces acting at the hand-tool interfaces. Such knowledge can be used to help understand the mechanisms of vibration-induced disorders and discomfort, and to help develop frequency weightings for assessing these effects. The establishment of typical values for human hand-arm impedance will foster these applications.

The response of the hand-arm system to vibration depends not only on the mechanical properties of the hand and arm, but also on the coupling between the hand and the vibrating surface. The major factors that could influence the response are as follows:

— direction of vibration with respect to the hand-arm system;

— geometry of the object grasped;

— forces exerted by the hand on the object;

— hand and arm postures;

— individual differences, such as tissue properties and anthropometric characteristics of the hand-arm system;

— vibration magnitude, because of the nonlinear properties of tissues.

The forces exerted by the hand are usually described in terms of the grip force and feed force. The latter is often called the “thrust”, “push” or “press” force.

In this International Standard, typical values for the mechanical impedance of the hand-arm system measured at the driving point of one bare hand are provided. They have been derived from the results of impedance measurements performed on groups of live male subjects by different investigators. Insufficient data are available from independent sources to specify hand-arm impedances for females.

There are large differences between the mean values of impedance reported in studies conducted independently, under nominally equivalent conditions. The variations have dictated the form in which the standardized male hand-arm impedance is presented. The most probable values of impedance modulus and phase are defined, as a function of frequency, by upper and lower envelopes, which encompass the mean values of all accepted data sets at each frequency. The envelopes have been constructed from segmental cubic spline functions, and define, at each frequency, the range of accepted values of the male hand-arm impedance. The mean of the accepted data sets, and standard deviation of the mean, are defined as a function of frequency, and represent the target values for all applications of this International Standard.

No impedance modulus or phase presented as a function of frequency in this International Standard corresponds precisely to the mean value measured in a single investigation involving human subjects, at all frequencies.

Mechanical vibration and shock — Mechanical impedance of the human hand-arm system at the driving point

1 Scope

This International Standard specifies the mechanical impedance of the human male hand-arm system at the driving point. Values of the impedance, expressed as modulus and phase, are provided for three orthogonal, translatory directions of excitation that correspond to the x_h-, y_h- and z_h-axes of the basicentric coordinate system.

NOTE 1 The basicentric coordinate system is defined in ISO 5349-1[2] and ISO 8727.[5]

The x_h-, y_h- and z_h-components of impedance are defined as a function of frequency, from 10 Hz to 500 Hz, for specified arm positions, grip and feed forces, handle diameters, and intensities of excitation. The components of impedance in the three directions are treated as being independent.

This International Standard can be used to define typical values of the mechanical impedance of the hand-arm system at the driving point, applicable to males under the circumstances specified. This International Standard can provisionally be applied to females.

Reference values of the mechanical impedance at the driving point are provided as a function of frequency for a specified grip and feed force.

NOTE 2 See Annex A.

These impedance values are intended for the determination of the transmissibility of resilient materials when loaded by the hand-arm system.

Mathematical representations of the hand-arm system that model the mean values of apparent mass or impedance are provided.

NOTE 3 See Annexes B to D.

A gloved hand-arm model is described, and the frequency dependence of vibration power absorption in the hand-arm system is also provided.

NOTE 4 See Annexes E and F.

To help conduct further measurement of the mechanical impedance, especially for circumstances that are not specified in this International Standard, information on the measurement of mechanical impedance is provided.

NOTE 5 See Annex G.

2 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

2.1
mechanical impedance of the hand-arm system at the driving point
Z_h
complex ratio of the dynamic force F acting on the hand contact surface and the vibration velocity input v to the hand, given by the equation $Z_h(\omega) = F(\omega)/v(\omega)$ [Equation (1)], where ω is the vibration frequency in radians per second

NOTE 1 The mechanical impedance can be derived from the apparent mass M_h of the hand-arm system, which is defined as the complex ratio of the dynamic force and the vibration acceleration a and is expressed by the equation $M_h(\omega) = F(\omega)/a(\omega)$ [Equation (2)].

NOTE 2 The relationship between the mechanical impedance and the apparent mass can be expressed by the equation $Z_h(\omega) = j\omega \cdot M_h(\omega)$ [Equation (3)], where

$$j = \sqrt{-1}$$

NOTE 3 These biodynamic response functions are generally complex, i.e. they possess real and imaginary parts, which can be expressed as modulus and phase.

3 Mechanical impedance of the hand-arm system at the driving point

The modulus and phase of the mechanical impedance of the hand-arm system at the driving point are given in Tables 1 to 3 and (for illustration) in Figures 1 to 3 at one-third-octave band centre frequencies, for three orthogonal directions of excitation. The directions correspond to the x_h-, y_h- and z_h-axes of the basicentric coordinate system for the hand (see Figure 5). Each table and figure contains three values of modulus and phase at each frequency, for each direction of motion, to reflect the range of values measured on male hands. The upper and lower values define the range of most probable values of impedance. The third value represents an overall mean of the human data, and defines the target value for all applications. The upper and lower limiting values at each frequency encompass the mean values of all data sets selected, and are shown by bold continuous curves in Figures 1 to 3. The central value at each frequency, shown by dashed curves in Figures 1 to 3, provides an estimate of the mean of all data sets selected, and forms the target value for all applications.

Numerical values are quoted up to three significant figures for the purposes of calculation, and do not reflect the precision of knowledge of the hand-arm impedance. Linear interpolation is permitted to obtain impedance values at frequencies other than those listed in Tables 1 to 3.

Applications that generate or employ values of impedance between the upper and lower limits at any frequency satisfy the requirements of this International Standard, and represent the group mean of the male hand-arm mechanical impedance at that frequency, or frequencies.

If an application only satisfies the requirements of this International Standard at certain frequencies, then those frequencies should be stated in any description of the application.

NOTE Because each set of the selected data represents the group mean of the individuals participating in the study, the impedance for a specific individual could be beyond the limits.

Table 1 — Values of the mechanical impedance of the hand-arm system at the driving point in the x_h-direction

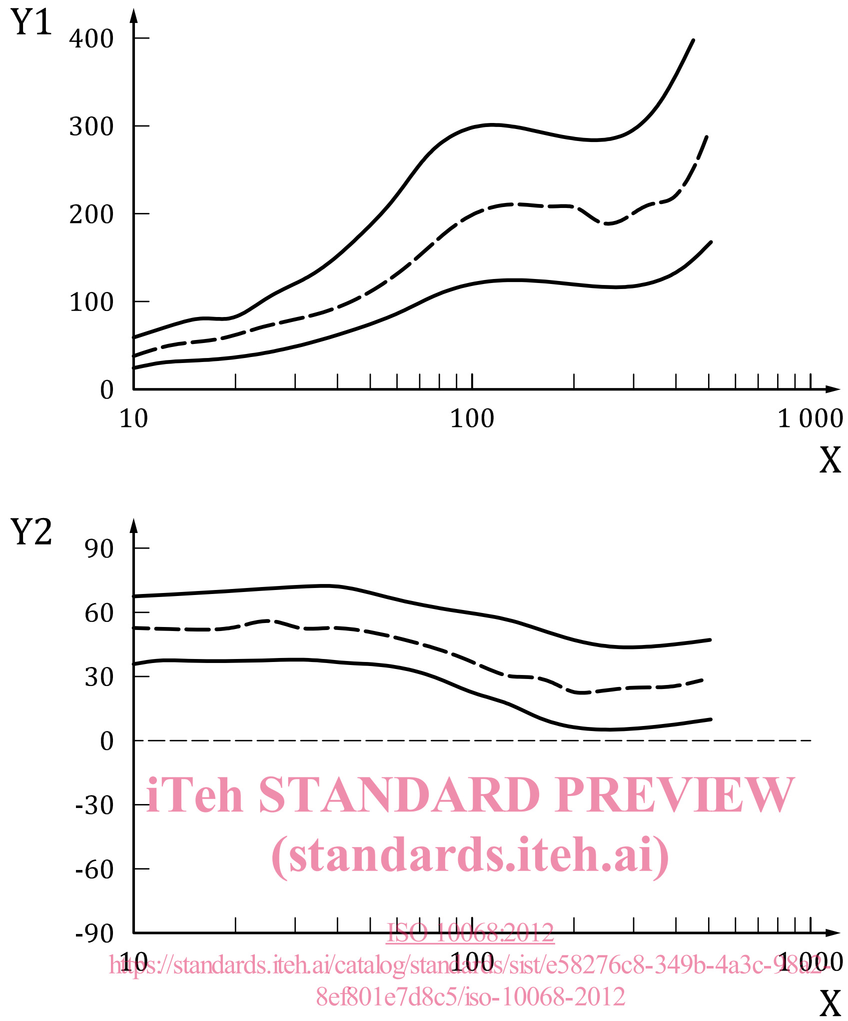
Frequency Hz	Modulus N·s/m			Phase degrees		
	Lower limit	Mean	Upper limit	Lower limit	Mean	Upper limit
10	24	38	59	36	53	68
12,5	30	49	71	38	53	69
16	33	54	80	38	53	70
20	36	64	84	38	54	71
25	43	72	104	38	57	72
31,5	51	80	125	38	53	73
40	62	95	154	37	53	73
50	74	112	189	36	51	70
63	90	140	233	33	47	66
80	109	172	280	29	43	63
100	120	199	300	23	37	60
125	124	211	302	18	31	57
160	123	210	294	11	29	52
200	120	208	287	7	23	48
250	119	189	287	6	24	45
315	120	207	302	6	25	44
400	134	224	360	8	26	45
500	168	292	442	10	29	47

Table 2 — Values of the mechanical impedance of the hand-arm system at the driving point in the y_h-direction

Frequency Hz	**Modulus** N·s/m			**Phase** degrees		
	Lower limit	**Mean**	**Upper limit**	**Lower limit**	**Mean**	**Upper limit**
10	21	55	80	20	39	55
12,5	23	62	90	15	35	54
16	26	70	106	11	32	52
20	30	86	119	6	31	49
25	35	96	128	1	23	44
31,5	40	88	132	−6	18	39
40	48	102	135	−12	7	30
50	55	101	130	−18	−1	22
63	61	93	117	−22	−2	16
80	64	86	106	−23	−5	10
100	63	86	106	−23	−9	7
125	60	80	106	−22	−11	6
160	54	77	107	−19	−7	7
200	49	71	108	−16	−6	9
250	45	67	110	−11	0	17
315	45	69	113	−7	8	30
400	51	71	118	−4	16	45
500	66	79	134	1	22	56

Table 3 — Values of the mechanical impedance of the hand-arm system at the driving point in the z_h-direction

Frequency Hz	Modulus N·s/m			Phase degrees		
	Lower limit	Mean	Upper limit	Lower limit	Mean	Upper limit
10	120	145	200	15	29	45
12,5	80	149	225	10	29	46
16	133	181	250	5	31	48
20	141	217	325	0	31	49
25	200	266	361	0	26	44
31,5	275	311	365	−2	16	27
40	240	315	358	−13	−1	6
50	220	263	321	−33	−13	3
63	140	216	285	−47	−15	1
80	95	170	240	−37	−11	−2
100	85	158	239	−12	−1	6
125	100	156	240	−5	6	20
160	108	163	247	5	16	30
200	113	184	271	10	21	34
250	150	212	320	13	21	29
315	150	235	363	5	20	30
400	190	243	365	2	21	32
500	185	254	362	7	21	30



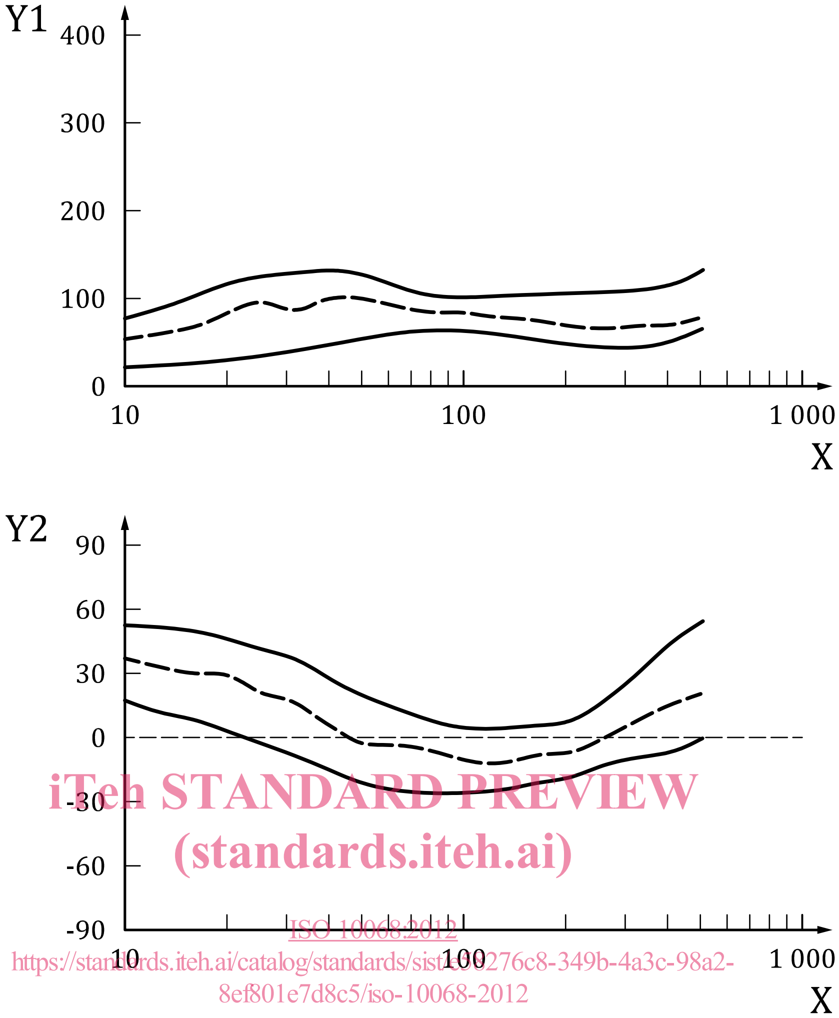
Key

X frequency (Hz)

Y1 modulus (N·s/m)

Y2 phase (degrees)

Figure 1 — Values of the mechanical impedance of the hand-arm system at the driving point in the x_h-direction (schematic)



Key

X frequency (Hz)

Y1 modulus (N·s/m)

Y2 phase (degrees)

Figure 2 — Values of the mechanical impedance of the hand-arm system at the driving point in the y_h-direction (schematic)

