INTERNATIONAL STANDARD

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

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

Reference numbe
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Contents

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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 voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

Annex A is an integral part of this International Standard. Annexes B to F are for information only.

Introduction

The mechanical impedance of the human hand and arm describes the motion of the hand-arm system in response to an oscillatory force impressed upon the hand. Such oscillatory forces occur, for example, during operation of a vibrating, hand-held power tool. The mechanical impedance of the hand-arm system is required for the design and development of

a) vibration-reducing and protective devices;

b) test rigs with which to measure the handle vibration of power tools.

Knowledge of this impedance permits the mechanical power transmitted to the hands to be estimated, and assists in the description of the biodynamic properties of the hand-arm system. The establishment of standardized values for human hand-arm impedance will foster the development of effective vibration-reducing and protective devices, and meaningful test procedures.

The response of the hand-arm system when the hand grasps a vibrating object depends on several factors. The most important of these are:

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

— the geometry of the object grasped;

— the forces exerted by the hand on the object;

— posture;

— muscle tone;

— anthropometric characteristics.

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, the free, mechanical impedance at the driving point is employed to describe the dynamic response of the human hand-arm system to forced motion of the hand, as a function of frequency. The values of free impedance 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.

The unexplained differences between the mean values of impedance reported in studies conducted independently, under nominally equivalent conditions, has dictated the form in which the standardized male hand-arm impedance is presented. A synthesis of measured values has been performed (see annex F). 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 weighted 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 — Free, mechanical impedance of the human hand-arm system at the driving point

1 Scope

This International Standard describes the free, mechanical impedance of the human male hand-arm system at the driving point. Values of the free 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 for the hand defined in ISO 5349 and ISO 8727. The x_h, y_h and z_h components of free 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 free impedance in the three directions are treated as being independent (see annex F).

This International Standard may be used to define typical values of the free, mechanical impedance of the hand-arm system at the driving point, applicable to males under the circumstances specified. For each impedance component, the free impedance is defined at each frequency by three values, 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 middle value represents an overall mean of the human data, and defines the target value for all applications. This International Standard may be provisionally applied to females.

Reference values of the free, mechanical impedance at the driving point are provided as a function of frequency for a specified grip and feed force in 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 values of free impedance are also provided in annexes C to E.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard 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 5349:1986, *Mechanical vibration — Guidelines for the measurement and the assessment of human exposure to hand-transmitted vibration*

ISO 8727:1997, *Mechanical vibration and shock — Human exposure — Biodynamic coordinate systems*

3 Definition

For the purposes of this International Standard, the following definition applies.

3.1
free impedance
complex ratio of the applied periodic excitation force at frequency f, $F(f)$, to the resulting vibration velocity at that frequency, $v(f)$, with all other connection points to the system “free”, that is, having zero externally applied force (see also ISO 2041)

$$Z(f) = F(f)/v(f)$$

NOTE 1 The free impedance is generally complex, that is, it possesses real and imaginary parts, which may be expressed as modulus and phase.

NOTE 2 This International Standard is based on measurements in which both force and velocity were measured at the same point, this being the point of introduction of vibration to the hand-arm system.

NOTE 3 The hand and arm are treated as a system in which translatory vibrations in the three mutually perpendicular directions are independent.

NOTE 4 Alternative descriptions of the dynamic response of the human hand-arm system have been used in the scientific literature (e.g. apparent mass).

4 Free, mechanical impedance of the hand-arm system at the driving point

The modulus and phase of the free, 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 as a function of frequency, for three orthogonal directions of excitation. The directions correspond to the x_h, y_h and z_h axes of the basicentric coordinate system according to ISO 5349 and ISO 8727. Each table and diagram contains three values of modulus and phase at each frequency, for each direction of motion. 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. Impedance values for one-third-octave band centre frequencies are given in annex B.

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 dotted curves in figures 1 to 3, provides an estimate of the weighted mean of all data sets selected, and forms the target value for all applications. The standard deviation of the mean (target) values are also listed in tables 1 to 3.

Applications that generate/employ values of impedance between the upper and lower limits at any frequency satisfy the requirements of this International Standard, and represent 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.

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

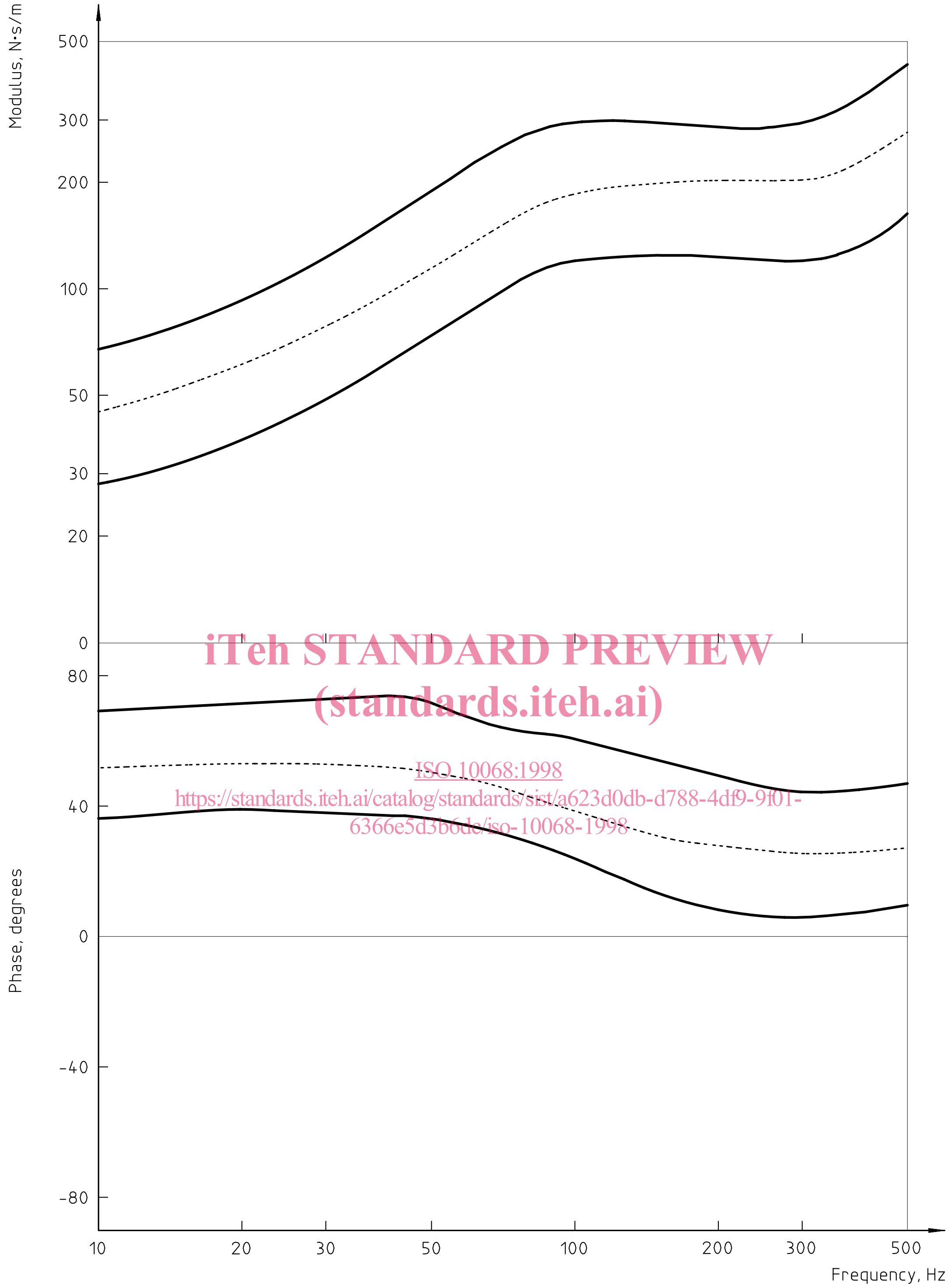
Frequency Hz	Modulus N·s/m				Phase degrees			
	Lower limit	Mean	Standard deviation	Upper limit	Lower limit	Mean	Standard deviation	Upper limit
10	24	38	13	59	36	53	14	68
15	33	50	12	69	38	53	8	70
20	36	64	14	84	38	54	8	71
25	43	72	19	104	38	57	12	72
30	49	81	22	120	38	55	12	73
35	55	88	25	137	37	53	12	73
40	62	95	28	154	37	53	10	73
45	68	104	29	171	37	52	10	72
50	74	112	31	189	36	51	10	70
60	86	132	38	223	34	50	10	67
70	98	153	46	255	32	46	10	64
80	109	172	54	280	29	43	11	63
90	115	186	54	291	26	40	11	62
100	120	199	56	300	23	37	11	60
125	124	211	58	302	18	31	10	57
150	124	219	61	297	13	27	11	54
175	122	217	59	291	10	25	14	50
250	119	189	44	287	6	24	13	45
300	119	187	54	297	6	25	13	44
350	124	203	51	321	6	25	13	44
400	134	224	55	360	8	26	12	45
450	150	265	90	405	9	27	12	46
500	168	292	111	442	10	29	12	47

Table 2 — Values of the free, 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	Standard deviation	Upper limit	Lower limit	Mean	Standard deviation	Upper limit
10	21	55	28	80	20	39	12	55
15	26	62	23	105	11	32	17	52
20	30	86	27	119	6	31	15	49
25	35	96	34	128	1	23	15	44
30	39	101	36	132	− 3	15	15	39
35	43	103	33	134	− 7	11	15	35
40	48	102	29	135	− 12	7	15	30
45	51	102	26	133	− 15	3	13	26
50	55	101	23	130	− 18	− 1	12	22
60	60	93	16	119	− 21	− 4	11	17
70	63	89	14	110	− 22	− 5	10	13
80	64	86	12	106	− 23	− 5	10	10
90	64	86	13	106	− 24	− 7	11	9
100	63	86	15	106	− 23	− 9	11	7
125	60	80	16	106	− 22	− 11	10	6
150	55	76	17	107	− 20	− 10	7	6
175	51	73	18	107	− 17	− 8	7	7
200	49	71	20	108	− 16	− 6	7	9
250	45	67	23	110	− 11	0	7	17
300	44	66	24	113	− 8	7	12	27
350	46	69	22	115	− 5	12	14	37
400	51	71	19	118	− 4	16	15	45
450	58	75	19	125	− 2	20	18	52
500	66	79	20	134	1	22	20	56

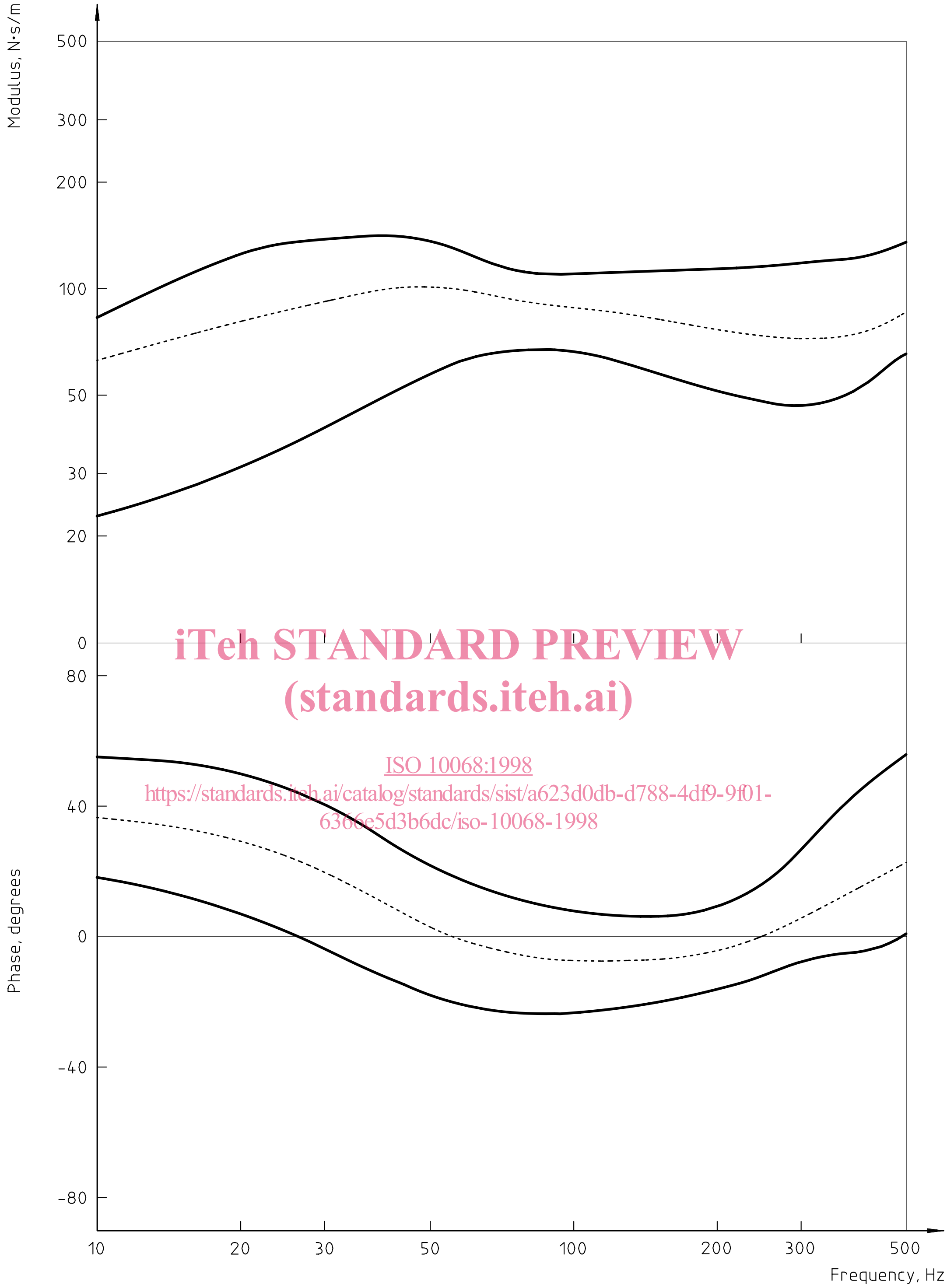
Table 3 — Values of the free, mechanical impedance of the hand-arm system at the driving point in the z_h direction

Frequency Hz	Modulus N·s/m				Phase degrees			
	Lower limit	Mean	Standard deviation	Upper limit	Lower limit	Mean	Standard deviation	Upper limit
10	100	153	34	200	15	30	10	44
15	107	175	60	235	2	25	12	41
20	112	190	70	260	− 4	19	22	38
25	116	200	70	275	− 11	15	22	34
30	120	212	75	295	− 16	10	18	31
35	122	219	79	304	− 21	5	16	28
40	125	220	80	305	− 26	1	16	27
45	126	215	72	299	− 30	− 1	17	25
50	126	207	61	288	− 33	− 4	18	25
60	123	186	40	257	− 38	− 6	23	25
70	117	169	28	230	− 37	− 5	24	26
80	109	160	30	219	− 31	− 3	22	28
90	106	160	37	219	− 26	0	19	29
100	105	160	47	227	− 21	2	15	30
125	110	175	65	257	− 10	8	11	31
150	117	181	85	288	− 2	13	10	31
175	124	190	89	310	2	16	8	31
200	130	200	84	325	6	18	7	32
250	146	216	65	345	8	19	5	33
300	157	229	68	353	7	20	7	35
350	163	238	67	359	6	20	12	39
400	169	246	63	365	5	20	14	43
450	175	255	63	370	6	21	13	47
500	183	265	64	377	7	23	13	49



NOTE For an explanation of the lines, see clause 4.

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



NOTE For an explanation of the lines, see clause 4.

Figure 2 — Values of the free, mechanical impedance of the hand-arm system at the driving point in the *y* direction