
**Mechanical vibration and shock —
Range of idealized values to
characterize human biodynamic
response under whole-body vibration**

*Vibrations et chocs mécaniques — Enveloppes de valeurs probables
caractérisant la réponse biodynamique d'individus soumis à des
vibrations globales du corps*

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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.

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*, Subcommittee SC 4, *Human exposure to mechanical vibration and shock*.

This third edition cancels and replaces the second edition (ISO 5982:2001), which has been technically revised. The main changes compared to the previous edition are as follows:

- Previously given ranges of idealized values for the apparent mass of the seated human body have been updated.
- The range of idealized values is now defined for seated individuals, with and without a back support, exposed to sinusoidal or broad-band random vibration in the x-axis, y-axis and z-axis with unweighted RMS acceleration lower or equal to 2 m/s².
- Idealized values of apparent mass for standing individuals, while exposed to vertical vibration (z-axis), have been added.

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.

Introduction

The biodynamic response of the seated human body subjected to vibration has widely been assessed in terms of driving-point mechanical impedance or apparent mass and seat-to-head transmissibility. While the first two functions relate to the force and motion at the point of input of vibration to the body ("to the body" transfer functions), the last function refers specifically to the transmission of motion through the body ("through the body" transfer function). Since biodynamic responses are non-linear with respect to vibration magnitude, those functions are defined for a specific range of vibration magnitudes. Knowledge of these functions under conditions representative of those encountered while driving specific types of vehicles can find applications in current laboratory procedures defined for assessing vehicle seat performance and for predicting whole-body vibration exposure levels on platforms of mobile machinery. Although such procedures currently require that specific tests be conducted with human subjects acting as test loads, these functions can form the basis for developing a mechanical system capable of simulating the human body or for deriving functions that can account for the human interface when the tests are being conducted with rigid masses. Such functions can further form the basis for developing analytical models representing the human body, which through combination with suitable suspension seat models can provide numerical means of estimating the seat performance and of achieving optimal seat suspension and cushion design. Notwithstanding the above applications, this document provides unification of available published data on the driving-point mechanical impedance, apparent mass and seat-to-head transmissibility response functions satisfying a specific set of conditions. In view of the restrictions imposed on posture and vibration excitation levels, the values defined for each of these functions can be more applicable to drivers of off-road, heavy road and industrial vehicles.

The response of the human body subjected to whole-body vibration is dependent on several factors, including

- a) subject mass,
- b) posture and back support,
- c) feet support and
- d) excitation amplitude.

In this document, the apparent mass and the seat-to-head transmissibility are employed to describe the biodynamic response characteristics of the human body to forced translational motion of the buttocks or feet, as a function of frequency.

The unexplained differences between the mean modulus and phase values of apparent mass and seat-to-head transmissibility reported in studies conducted independently, under a similar range of experimental conditions, has dictated the form in which the standardized values for these functions is presented. A synthesis of measured values has been performed using data published in the literature. The most probable range of values of apparent mass and seat-to-head transmissibility modulus and phase are defined as a function of frequency by upper and lower limit envelope curves, which encompass the mean values of all data sets, at each frequency. The smoothened envelopes have been constructed from successive piecewise approximations using a fixed number of points while creating an overlap. The mean of the accepted data sets, weighted according to the number of subjects involved, and standard deviation computed with respect to the weighted mean, are defined as a function of frequency, and represent the target values for all applications of this document. Any data that fall within the range of idealized values defined by upper and lower limit envelope curves can be considered to be an acceptable representation of the biodynamic response functions of the human body under the specific conditions defined.

No modulus or phase presented as a function of frequency in this document corresponds precisely to the mean value measured in a single investigation involving human subjects at all frequencies. Furthermore, measured data for a single subject can appear out of range of the upper and lower limit envelope curves.

Major changes to previously given ranges of idealized values for the apparent mass of the seated human body were considered necessary in view of the new data available since the publication of the second edition (ISO 5982:2001). The second edition only considered the driving-point mechanical impedance/apparent mass of seated individuals, without a back support, exposed to vertical vibration (z-axis). As part of this document, a range of idealized values is defined for seated individuals, with and without a back support, exposed to sinusoidal or broad-band random vibration in the x-axis, y-axis and z-axis with unweighted RMS acceleration lower or equal to 2 m/s^2 . Idealized values of apparent mass for standing individuals, while exposed to vertical vibration (z-axis), have also been added. Values for seat-to-head transmissibility (STHT) remained mostly unchanged and are still provided for seated individuals without a back support while exposed to z-axis vertical vibration.

This document incorporates the most recent data to have been published on the apparent mass and seat-to-head transmissibility, while satisfying the conditions specified above. [Annex A](#) provides information on the selection of published data to define the range of idealized values of apparent mass and seat-to-head transmissibility. The frequency ranges for defining these values are limited to 0,5 Hz to 20 Hz for vertical vibration (z-axis) and to 0,5 Hz to 10 Hz for lateral (y-axis) and fore-aft (x-axis) vibration, since predominant vibrations are known to occur within those ranges for several types of off-road, heavy road and industrial vehicles. In [Annex B](#), an analytical model of the seated human body is provided to satisfy the range of idealized values defined for the apparent mass and seat-to-head transmissibility functions. Alternatively, mathematical expressions in the form of transfer functions are provided in [Annex C](#) to approximate the mean (target) values defined for these functions. Finally, values for the apparent mass are provided in [Annex D](#) for three specific body masses ranges on the basis of a study involving 27 male subjects.

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Mechanical vibration and shock — Range of idealized values to characterize human biodynamic response under whole-body vibration

1 Scope

This document describes the range of idealized values of the apparent mass modulus and phase applicable to seated individuals with and without a back support subjected to x-, y- and z-axis sinusoidal or broad-band random vibration and to standing individuals subjected to z-axis sinusoidal or broad-band random vibration under specific experimental conditions. Additionally, this document describes the range of idealized values of seat-to-head transmissibility modulus and phase applicable to seated individuals without a back support subjected to z-axis sinusoidal or broad-band random vibration.

The ranges of idealized values defined in this document are considered to be valid for subjects on a rigid seat (or standing on a rigid platform for z-axis only), with feet supported and vibrated. The range of idealized seat-to-head transmissibility values is considered to be applicable also to the condition with the feet hanging freely. For seated individuals subjected to sinusoidal or broad-band random vibration, the apparent mass values are defined over the frequency range of 0,5 Hz to 10 Hz for the x-axis and y-axis, and over the frequency range of 0,5 Hz to 20 Hz for the z-axis. The frequency and amplitude characteristics of the vibration fall within the range for which most vibration exposure is likely to predominate while driving vehicles such as agricultural tractors, earth-moving machinery and fork-lift trucks. Application to automobiles is not covered by this document in view of the lack of a meaningful database for conditions involving posture and vibration excitation levels most likely associated with car driving.

The upper and lower values of modulus and phase defined at each frequency for each of the biodynamic response functions considered represent the range of most probable or idealized values. The middle values represent overall weighted means of the human data and define the target values for general applications. Such applications can involve the development of mechanical analogues for laboratory seat testing, or of functions to correct for the human interface when representing the body as a rigid mass, or the development of analytical human body models to be used for whole-body vibration exposure estimations or for seat and cushion design optimization.

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 5805, *Mechanical vibration and shock — Human exposure — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 5805 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/>

3.1 apparent mass

$M(f)$

complex ratio of applied periodic excitation force at frequency f , $F(f)$, to the resulting vibration acceleration at that frequency, $a(f)$, measured at the same point and in the same direction as the applied force, as given by [Formula \(1\)](#)

$$M(f) = \frac{F(f)}{a(f)} \quad (1)$$

Note 1 to entry: The apparent mass is a complex quantity (i.e. it possesses real and imaginary parts) from which the modulus and phase can be computed.

Note 2 to entry: This document is based on measurements in which both force and acceleration were measured at the same point, this being the point of introduction of vibration to the body, namely the buttocks (seat-body interface) or the feet.

Note 3 to entry: In the case of non-harmonic vibration, apparent mass is determined from the force and acceleration spectra.

3.2 driving-point mechanical impedance

$z(f)$

complex ratio of applied periodic excitation force at frequency f , $F(f)$, to the resulting vibration velocity at that frequency, $v(f)$, measured at the same point and in the same direction as the applied force, as given by [Formula \(2\)](#)

$$z(f) = \frac{F(f)}{v(f)} = j2\pi f M(f) \quad (2)$$

where

$M(f)$ is the apparent mass;

j represents the complex phasor between the mechanical impedance and apparent mass ($j = \sqrt{-1}$).

Note 1 to entry: The relationship between driving-point mechanical impedance and apparent mass is entirely determined by the fixed relationship between velocity and acceleration for which a 90° phase difference exists under periodic excitation.

Note 2 to entry: In the case of non-harmonic vibration, driving-point mechanical impedance is determined from the force and velocity spectra.

3.3 seat-to-head transmissibility

complex non-dimensional ratio of the response motion of the head to the forced vibration motion at the buttocks (seat-body interface)

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

Note 2 to entry: The seat-to-head transmissibility is a complex quantity (i.e. it possesses real and imaginary parts) from which the non-dimensional modulus and the phase can be computed.

Note 3 to entry: In the case of non-harmonic vibration, seat-to-head transmissibility is determined from the motion spectra.

4 Definition of values of apparent mass of the human body under vibration

4.1 Apparent mass of the seated body under x-axis vibration

The modulus and phase of the apparent mass of the seated body with and without a back support are given in [Tables 1](#) and [2](#), respectively, and (for illustration) in [Figures 1](#) and [2](#) as a function of frequency, for the x-axis direction of excitation. According to the definitions, the modulus is given in terms of kilograms for apparent mass. The table and diagram contain three values of modulus and phase at each frequency. Numerical values are quoted up to four significant figures for the purpose of calculation, and do not reflect the precision of knowledge of the apparent mass. Linear interpolation is permitted to obtain values at frequencies other than those listed in [Tables 1](#) and [2](#) at one-third-octave band centre frequencies.

The upper and lower limiting values at each one-third-octave band centre frequency encompass the mean values of all data sets selected, and are shown by continuous curves in [Figures 1](#) and [2](#). The central value at each frequency, shown by dashed curves in [Figures 1](#) and [2](#), provides an estimate of the weighted mean of all data sets selected, and forms the target value for all applications. The standard deviations computed with respect to the weighted mean (target) values are also listed in [Tables 1](#) and [2](#).

Applications shall generate/employ values of apparent mass between the upper and lower limits given in [Tables 1](#) and [2](#) at any frequency, and represent “to the body” transfer functions applicable to the seated human body under the conditions specified and over the frequency range of 0,5 Hz to 10 Hz.

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

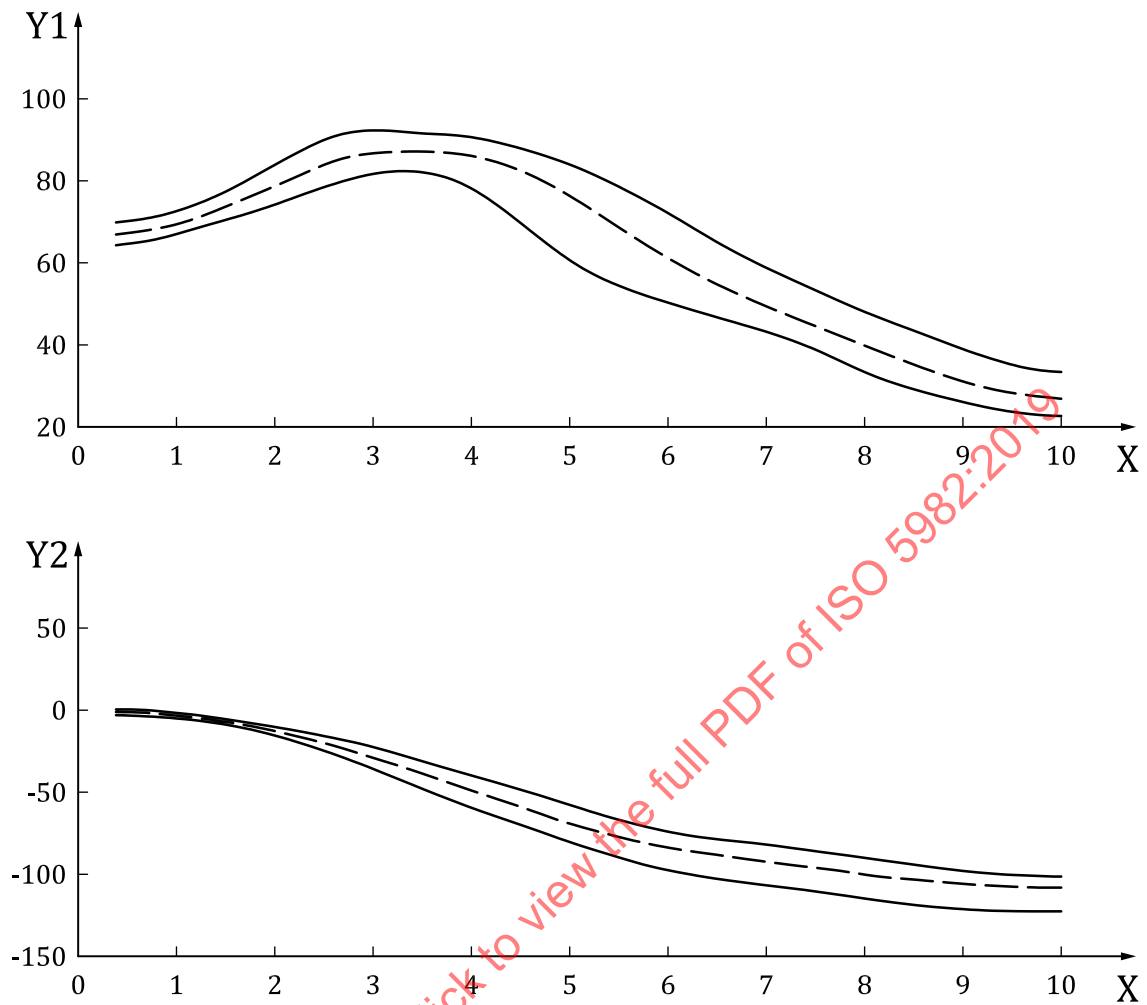
4.2 Applicability of values of apparent mass of the seated body under x-axis vibration

The values of apparent mass are applicable to the seated human body, subjected to sinusoidal or broad-band random fore-aft vibration, while seated on a rigid surface with the feet resting flat on the base platform and the back being supported and unsupported. The limits of applicability approximately correspond to the range of measurement conditions over which data were obtained, as follows:

- a) the posture is described as erect seated with or without backrest support, while the feet are supported and vibrated;
- b) the angle for the back support is ranging from 90° to 102° for the condition with a backrest support;
- c) the mass of the subjects ranges from 57 kg to 92 kg for the condition with a backrest support, and from 55 kg to 103,6 kg for the condition without a backrest support;
- d) the RMS amplitude of unweighted sine and random excitation is between 0,4 m/s² and 1,0 m/s² within the frequency range of 0,5 Hz to 10 Hz.

Table 1 — Modulus and phase of the mean (target) and range of idealized apparent mass of the seated body with a back support under x-axis vibration

Frequency Hz	Modulus kg				Phase °			
	Mean	Upper limit	Lower limit	Standard deviation	Mean	Upper limit	Lower limit	Standard deviation
0,5	65,3	68,8	62,8	2,4	-0,1	1,8	-2,8	1,9
0,63	65,6	68,5	63,8	1,8	-0,3	1,2	-2,7	1,6
0,8	68,2	70,0	66,7	1,2	-1,2	-0,9	-1,8	0,4
1	69,5	72,1	67,8	1,7	-1,8	-1,2	-2,4	0,5
1,25	71,5	74,9	68,9	2,3	-4,7	-3,8	-5,9	0,8
1,6	74,8	78,3	71,1	2,7	-8,2	-7,3	-9,4	0,9
2	78,7	83,4	73,8	3,8	-12,2	-10,3	-14,6	1,9
2,5	85,2	92,5	79,3	5,3	-20,1	-15,0	-24,7	4,5
3,15	87,5	92,5	82,8	3,9	-31,4	-24,0	-38,4	6,6
4	86,4	90,8	78,9	4,9	-49,2	-40,6	-60,7	8,5
5	76,1	83,8	60,1	9,4	-69,7	-58,5	-80,8	8,9
6,3	56,7	67,3	47,8	7,4	-87,1	-77,4	-101,3	9,7
8	39,4	47,8	33,3	6,8	-100,6	-90,7	-115,2	9,5
10	28,4	35,3	23,6	5,6	-107,6	-100,3	-122,2	8,9

**Key**

X frequency in Hz

Y1 modulus in kg

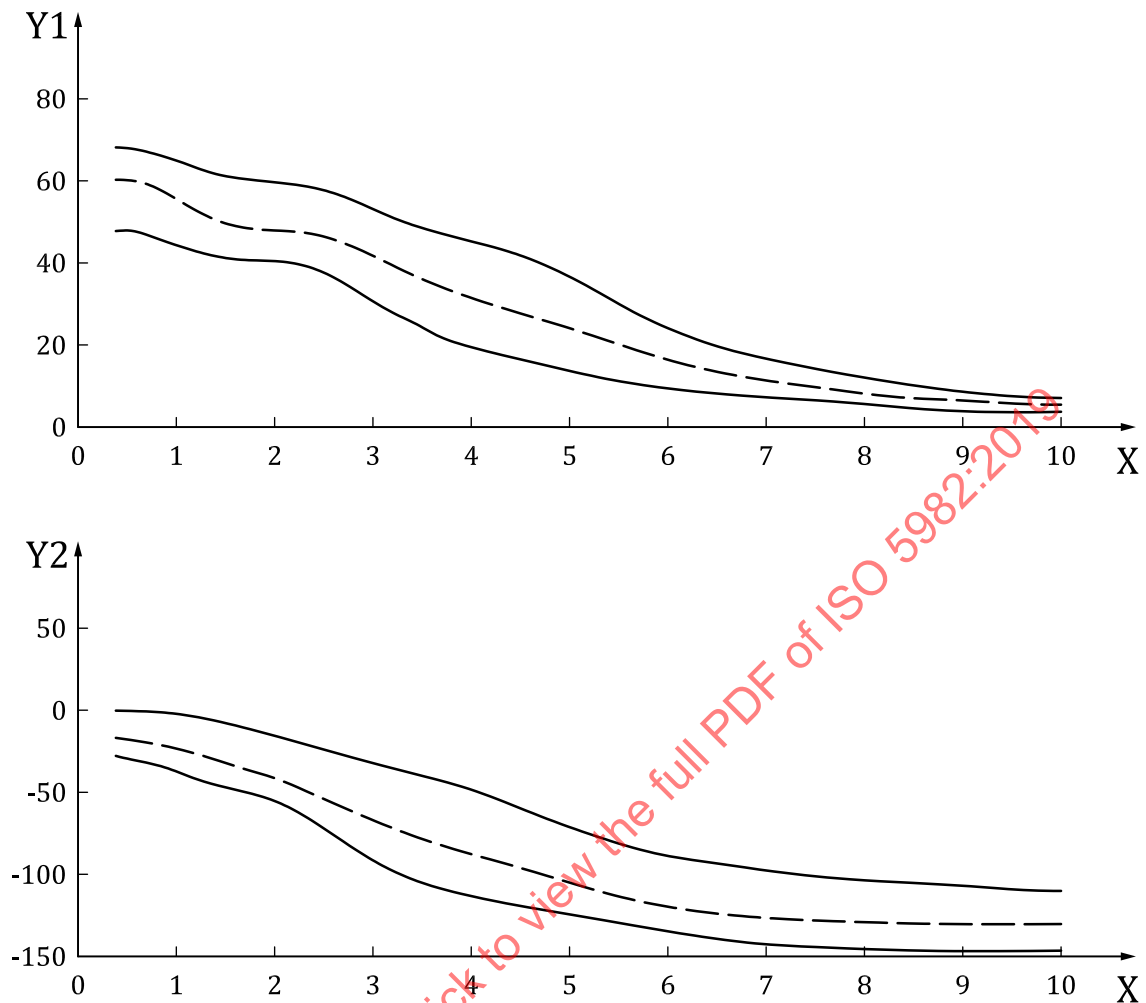
Y2 phase in °

NOTE For an explanation of the curves, see [4.1](#).

Figure 1 — Mean (target) and range of idealized values for the apparent mass of the seated body with a back support under x-axis vibration

Table 2 — Modulus and phase of the mean (target) and range of idealized apparent mass of the seated body without a back support under x-axis vibration

Frequency Hz	Modulus kg				Phase °			
	Mean	Upper limit	Lower limit	Standard deviation	Mean	Upper limit	Lower limit	Standard deviation
0,5	62,9	70,3	48,6	8,2	-12,8	1,4	-20,1	9,8
0,63	63,6	71,0	48,5	8,7	-13,6	1,2	-21,6	10,3
0,8	61,7	68,2	48,5	7,1	-19,7	-1,0	-34,0	14,2
1	58,5	66,9	46,8	7,0	-25,3	-1,2	-40,1	17,4
1,25	49,5	62,7	40,2	8,5	-28,7	-4,3	-45,5	16,7
1,6	46,3	58,5	39,1	6,4	-33,5	-9,3	-48,4	14,0
2	48,7	60,1	41,8	6,8	-39,3	-14,6	-50,1	13,0
2,5	47,9	59,4	38,8	7,3	-54,9	-24,6	-72,9	16,9
3,15	40,3	51,5	28,6	6,9	-71,1	-33,7	-97,5	21,1
4	31,4	45,3	19,1	8,4	-87,5	-49,3	-113,8	22,1
5	23,8	36,3	13,6	8,0	-105,6	-71,6	-124,8	19,2
6,3	14,5	21,2	8,5	4,3	-122,6	-92,0	-137,9	16,8
8	8,2	12,0	5,4	2,3	-129,1	-103,7	-145,5	15,1
10	5,7	7,5	3,6	1,3	-130,2	-108,6	-147,2	14,3

**Key**

X frequency in Hz

Y1 modulus in kg

Y2 phase in °

NOTE For an explanation of the curves, see [4.1](#).

Figure 2 — Mean (target) and range of idealized values for the apparent mass of the seated body without a back support under x-axis vibration

4.3 Apparent mass of the seated body under y-axis vibration

The modulus and phase of the apparent mass of the seated body with and without a back support are given in [Tables 3](#) and [4](#), respectively, and (for illustration) in [Figures 3](#) and [4](#) as a function of frequency, for the y-axis direction of excitation. According to the definitions, the modulus is given in terms of kilograms for apparent mass. The table and diagram contain three values of modulus and phase at each frequency. Numerical values are quoted up to four significant figures for the purpose of calculation, and do not reflect the precision of knowledge of the apparent mass. Linear interpolation is permitted to obtain values at frequencies other than those listed in [Tables 3](#) and [4](#) at one-third-octave band centre frequencies.

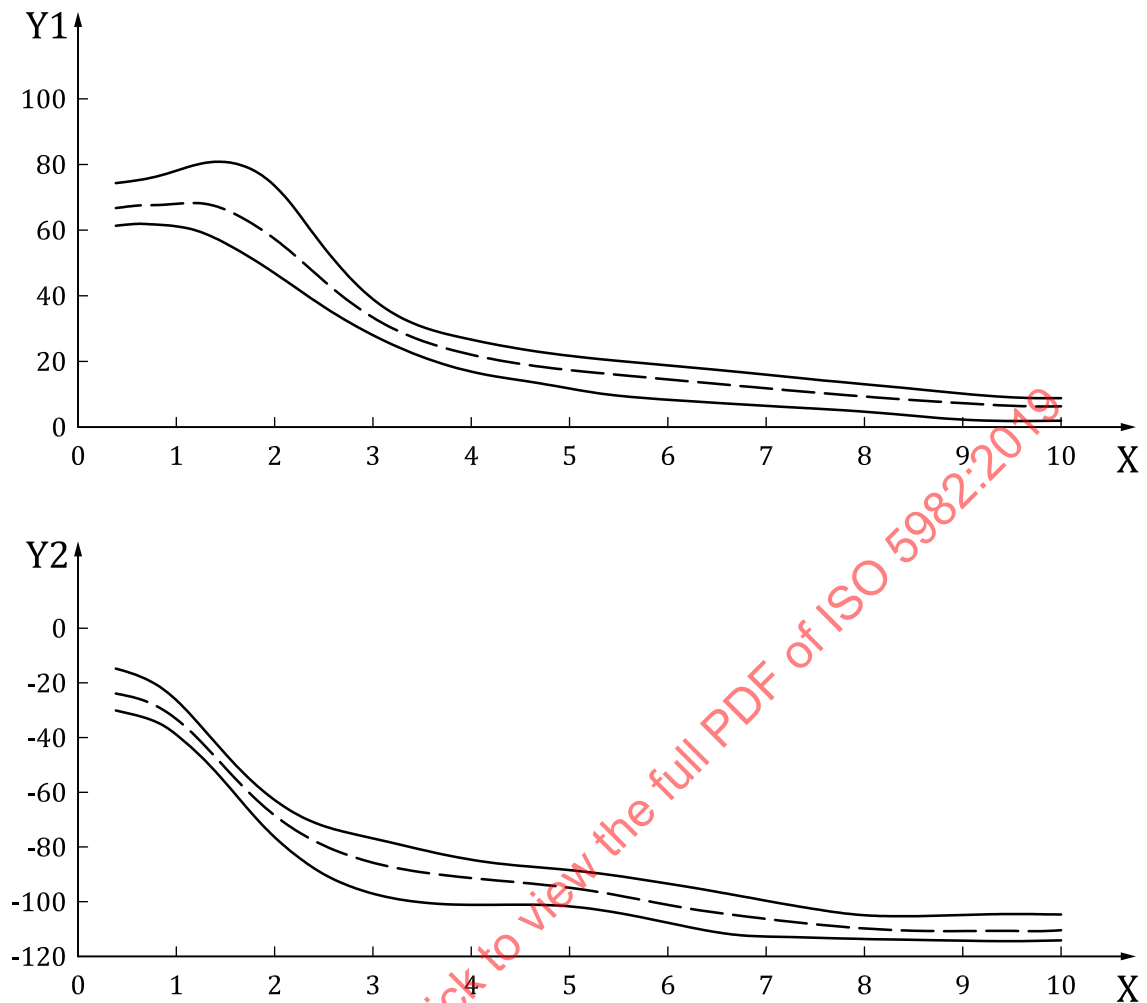
See [4.1](#) for more details.

4.4 Applicability of values of apparent mass of the seated body under y-axis vibration

The values of apparent mass are applicable to the seated human body, subjected to sinusoidal or broad-band random lateral vibration, while seated on a rigid surface with the feet resting flat on the base platform and the back being supported and unsupported. The limits of applicability approximately correspond to the range of measurement conditions over which data were obtained, and are identical to those described in 4.2.

Table 3 — Modulus and phase of the mean (target) and range of idealized apparent mass of the seated body with a back support under y-axis vibration

Frequency Hz	Modulus kg				Phase °			
	Mean	Upper limit	Lower limit	Standard deviation	Mean	Upper limit	Lower limit	Standard deviation
0,5	65,3	72,9	59,7	5,3	-19,8	-9,8	-26,7	6,5
0,63	65,6	74,0	59,8	5,8	-19,6	-10,6	-25,7	5,7
0,8	67,8	77,0	63,0	5,7	-23,4	-17,1	-28,1	4,2
1	70,6	79,1	64,6	5,6	-29,7	-22,8	-34,8	4,7
1,25	70,9	82,7	63,0	7,4	-39,7	-33,8	-44,8	4,7
1,6	67,1	83,3	55,2	11,7	-56,9	-52,8	-61,5	3,9
2	58,9	80,1	46,4	13,5	-71,5	-66,6	-79,4	5,0
2,5	43,3	52,0	36,0	6,4	-80,7	-73,0	-92,1	7,1
3,15	30,5	34,4	26,2	3,2	-86,9	-77,5	-98,7	8,0
4	21,7	26,5	16,7	3,3	-91,4	-85,3	-101,1	6,6
5	17,3	21,7	11,5	3,6	-95,3	-88,4	-101,9	5,6
6,3	13,4	17,6	7,7	3,6	-103,1	-96,0	-110,0	5,6
8	9,2	12,8	4,1	3,2	-109,5	-104,4	-113,6	3,7
10	6,5	9,1	1,8	2,7	-110,7	-104,5	-114,3	3,9

**Key**

X frequency in Hz

Y1 modulus in kg

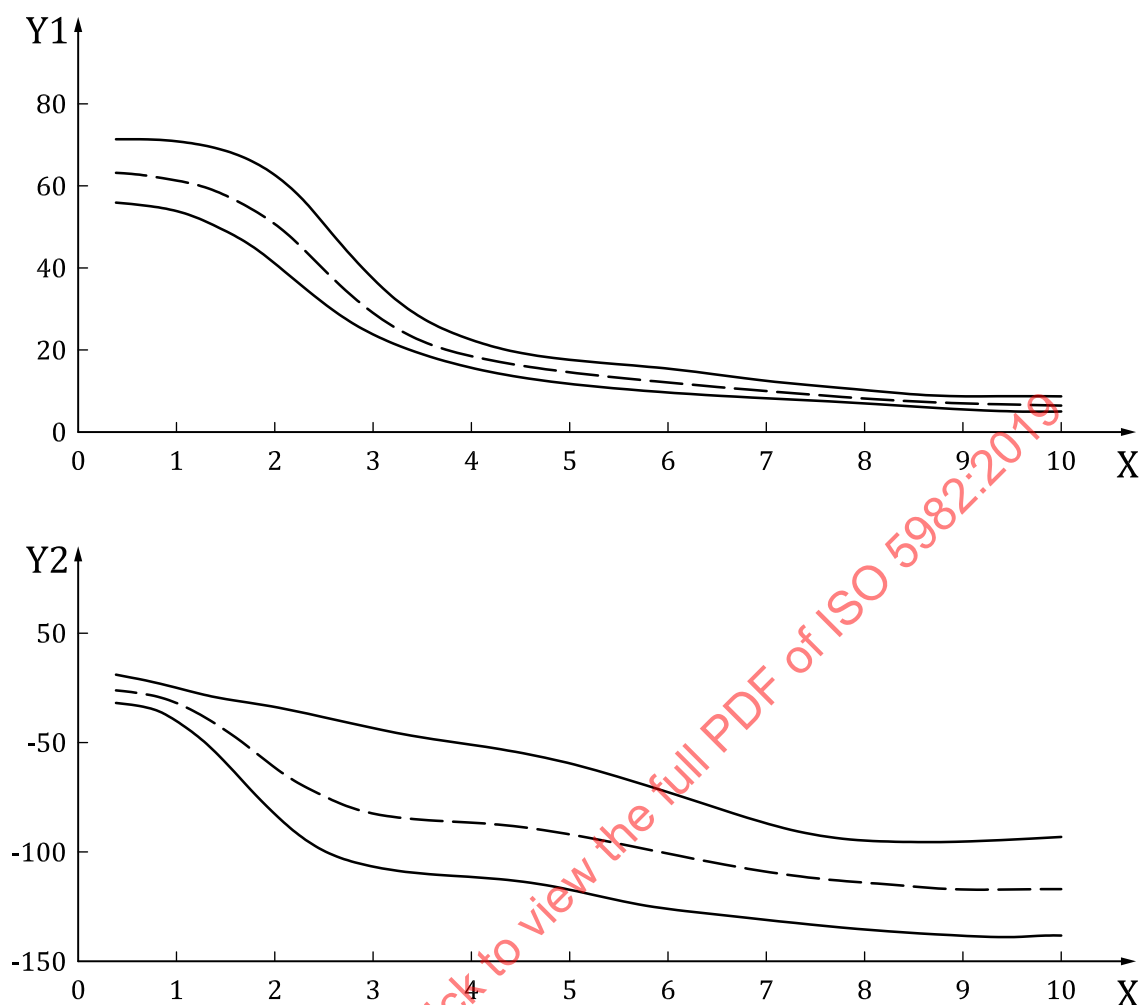
Y2 phase in °

NOTE For an explanation of the curves, see [4.1](#).

Figure 3 — Mean (target) and range of idealized values for the apparent mass of the seated body with a back support under y-axis vibration

Table 4 — Modulus and phase of the mean (target) and range of idealized apparent mass of the seated body without a back support under y-axis vibration

Frequency Hz	Modulus kg				Phase °			
	Mean	Upper limit	Lower limit	Standard deviation	Mean	Upper limit	Lower limit	Standard deviation
0,5	64,5	72,0	56,7	6,5	-23,1	-15,1	-29,6	7,4
0,63	64,9	73,0	56,7	6,9	-23,8	-17,6	-29,4	5,9
0,8	64,7	74,0	56,7	7,1	-27,5	-25,4	-29,0	1,9
1	62,5	72,0	55,8	6,7	-30,5	-26,5	-35,7	4,6
1,25	59,2	70,1	50,6	7,3	-34,0	-27,8	-43,8	6,4
1,6	58,6	68,6	50,5	6,8	-46,3	-30,2	-63,0	14,8
2	52,8	66,2	41,7	7,7	-61,9	-33,6	-86,6	23,3
2,5	39,2	50,9	30,3	6,5	-76,7	-38,4	-102,0	29,0
3,15	26,3	33,3	22,4	3,6	-83,7	-44,0	-107,6	30,1
4	18,3	22,1	15,5	2,4	-86,4	-50,9	-111,6	27,0
5	14,9	17,8	11,8	2,2	-92,3	-60,0	-117,5	24,6
6,3	11,6	14,4	9,3	1,9	-103,6	-77,6	-127,7	20,7
8	8,4	10,3	6,9	1,3	-113,8	-93,8	-135,2	16,9
10	6,7	8,8	5,2	1,3	-116,9	-93,7	-138,4	18,7

**Key**

X frequency in Hz

Y1 modulus in kg

Y2 phase in °

NOTE For an explanation of the curves, see [4.1](#).

Figure 4 — Mean (target) and range of idealized values for the apparent mass of the seated body without a back support under y-axis vibration

4.5 Apparent mass of the seated body under z-axis vibration

The modulus and phase of the apparent mass of the seated body with and without a back support are given in [Tables 5](#) and [6](#), respectively, and (for illustration) in [Figures 5](#) and [6](#) as a function of frequency, for the z-axis direction of excitation. According to the definitions, the modulus is given in terms of kilograms for apparent mass. The table and diagram contain three values of modulus and phase at each frequency. Numerical values are quoted up to four significant figures for the purpose of calculation, and do not reflect the precision of knowledge of the apparent mass. Linear interpolation is permitted to obtain values at frequencies other than those listed in [Tables 5](#) and [6](#) at one-third-octave band centre frequencies.

Applications shall generate/employ values of apparent mass between the upper and lower limits given in [Tables 5](#) and [6](#) at any frequency, and represent “to the body” transfer functions applicable to the seated human body under the conditions specified and over the frequency range of 0,5 Hz to 20 Hz.

See 4.1 for more details.

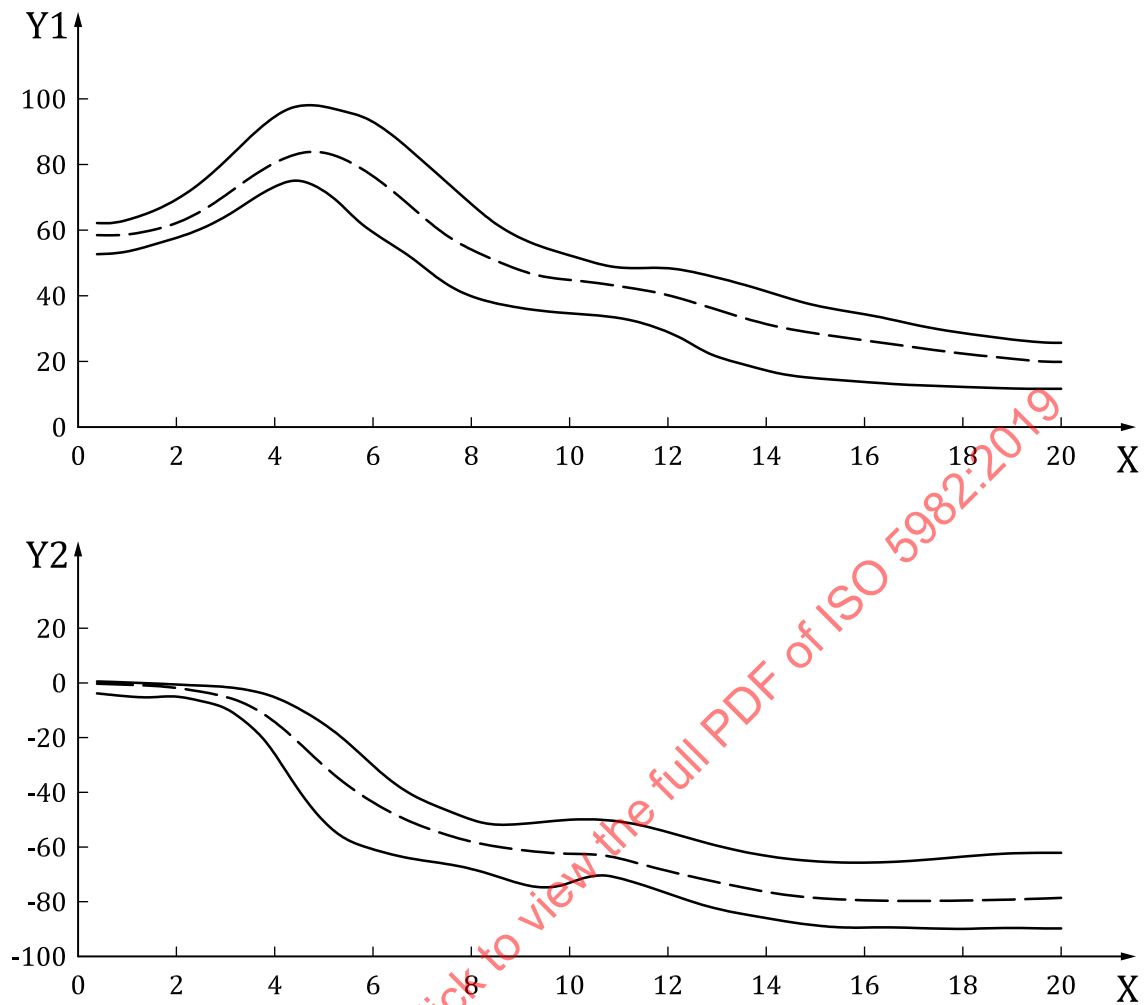
4.6 Applicability of values of apparent mass of the seated body under z-axis vibration

The values of apparent mass are applicable to the seated human body, subjected to sinusoidal or broad-band random vertical vibration, while seated on a rigid surface with the feet resting flat on the base platform and the back being supported and unsupported. The limits of applicability approximately correspond to the range of measurement conditions over which data were obtained, as follows:

- the posture is described as erect seated with or without backrest support, while the feet are supported and vibrated;
- the angle for the back support is ranging from 90° to 102° for the condition with a backrest support;
- the mass of the subjects ranges from 62 kg to 106 kg for the condition with a backrest support, and from 49 kg to 107 kg for the condition without a backrest support;
- the RMS amplitude of unweighted sine and random excitation within the frequency range of 0,5 Hz to 20 Hz is between 0,63 m/s² and 1,0 m/s² for the condition with a backrest support and between 0,8 m/s² and 2,0 m/s² for the condition without a backrest support.

Table 5 — Modulus and phase of the mean (target) and range of idealized apparent mass of the seated body with a back support under z-axis vibration

Frequency Hz	Modulus kg				Phase °			
	Mean	Upper limit	Lower limit	Standard deviation	Mean	Upper limit	Lower limit	Standard deviation
0,5	58,6	62,4	52,5	3,6	0,2	0,8	-0,3	0,4
0,63	58,8	62,5	52,6	3,6	0,1	0,9	-0,5	0,5
0,8	58,7	62,6	53,0	3,4	-0,9	0,7	-8,5	2,7
1	58,8	63,2	54,0	3,2	-0,8	0,4	-6,7	2,1
1,25	59,2	64,1	53,9	3,4	-0,8	0,2	-5,3	1,6
1,6	60,6	66,5	56,7	3,5	-1,2	-0,2	-4,6	1,2
2	62,6	69,4	58,1	3,8	-1,7	-0,4	-5,0	1,2
2,5	66,1	74,9	60,5	4,5	-2,9	-0,9	-6,0	1,4
3,15	71,8	83,2	65,5	5,8	-5,4	-1,7	-9,8	2,6
4	81,5	95,9	74,0	6,8	-14,5	-5,2	-26,2	7,3
5	83,9	97,6	72,0	8,0	-30,8	-15,3	-51,0	12,3
6,3	72,5	89,5	56,2	10,6	-47,1	-35,0	-62,2	9,7
8	54,3	67,9	40,4	7,9	-57,9	-49,4	-68,6	6,2
10	45,1	52,6	34,7	5,8	-62,8	-50,5	-72,6	8,0
12,5	37,5	46,3	24,9	7,0	-71,1	-57,3	-80,0	8,9
16	26,4	34,2	13,9	6,9	-78,9	-64,8	-89,2	8,6
20	21,1	27,2	11,8	5,4	-79,0	-62,8	-90,0	9,2

**Key**

X frequency in Hz

Y1 modulus in kg

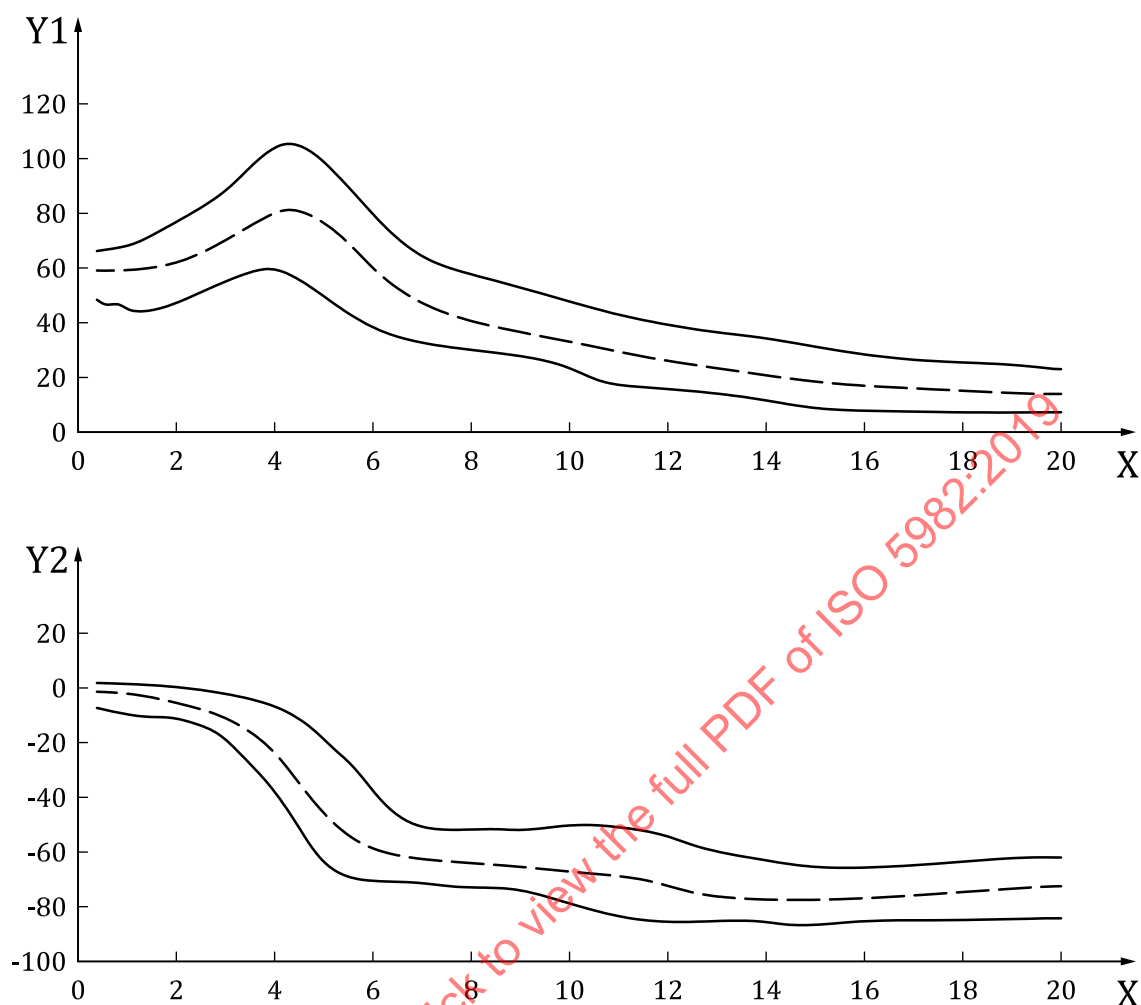
Y2 phase in °

NOTE For an explanation of the curves, see [4.1](#).

Figure 5 — Mean (target) and range of idealized values for the apparent mass of the seated body with a back support under z-axis vibration

Table 6 — Modulus and phase of the mean (target) and range of idealized apparent mass of the seated body without a back support under z-axis vibration

Frequency Hz	Modulus kg				Phase °			
	Mean	Upper limit	Lower limit	Standard deviation	Mean	Upper limit	Lower limit	Standard deviation
0,5	60,4	66,1	56,2	3,7	-1,1	2,8	-7,4	3,5
0,63	60,5	66,3	56,1	3,8	-1,4	3,5	-9,0	4,2
0,8	58,0	67,0	40,1	6,7	-1,3	2,8	-8,1	3,7
1	58,8	68,1	40,7	6,8	-2,5	2,2	-11,1	4,0
1,25	59,8	69,8	42,7	6,7	-2,8	1,1	-10,4	3,5
1,6	61,0	73,4	45,3	7,1	-3,7	-0,3	-10,1	3,1
2	61,8	77,1	47,9	8,2	-5,1	1,2	-11,6	3,4
2,5	65,9	83,0	51,6	8,8	-7,7	-1,4	-12,8	3,2
3,15	71,9	89,9	56,6	9,5	-11,5	-2,5	-20,2	4,3
4	81,2	105,8	60,3	12,5	-23,8	-6,9	-38,7	8,2
5	76,8	98,8	49,7	13,8	-46,3	-18,8	-64,2	12,9
6,3	55,5	74,1	36,3	10,4	-60,3	-43,5	-70,8	7,8
8	40,8	57,9	29,9	7,3	-63,9	-51,8	-72,9	5,8
10	32,7	47,7	22,5	6,3	-67,3	-50,9	-79,2	8,6
12,5	24,6	37,9	14,6	6,6	-74,3	-57,5	-85,6	8,8
16	17,2	28,9	8,4	5,4	-76,5	-64,8	-85,8	7,2
20	14,5	24,6	7,2	4,6	-73,6	-62,8	-84,7	7,5

**Key**

X frequency in Hz

Y1 modulus in kg

Y2 phase in °

NOTE For an explanation of the curves, see 4.1.

Figure 6 — Mean (target) and range of idealized values for the apparent mass of the seated body without a back support under z-axis vibration

4.7 Apparent mass of the standing body under z-axis vibration

The modulus and phase of the apparent mass of the standing body are given in [Table 7](#) and (for illustration) in [Figure 7](#) as a function of frequency, for the z-axis direction of excitation. According to the definitions, the modulus is given in terms of kilograms for apparent mass. The table and diagram contain three values of modulus and phase at each frequency. Numerical values are quoted up to four significant figures for the purpose of calculation, and do not reflect the precision of knowledge of the apparent mass. Linear interpolation is permitted to obtain values at frequencies other than those listed in [Table 7](#) at one-third-octave band centre frequencies.

Applications shall generate/employ values of apparent mass between the upper and lower limits given in [Table 7](#) at any frequency, and represent “to the body” transfer functions applicable to the standing human body under the conditions specified and over the frequency range of 0,5 Hz to 20 Hz.

See [4.1](#) for more details.

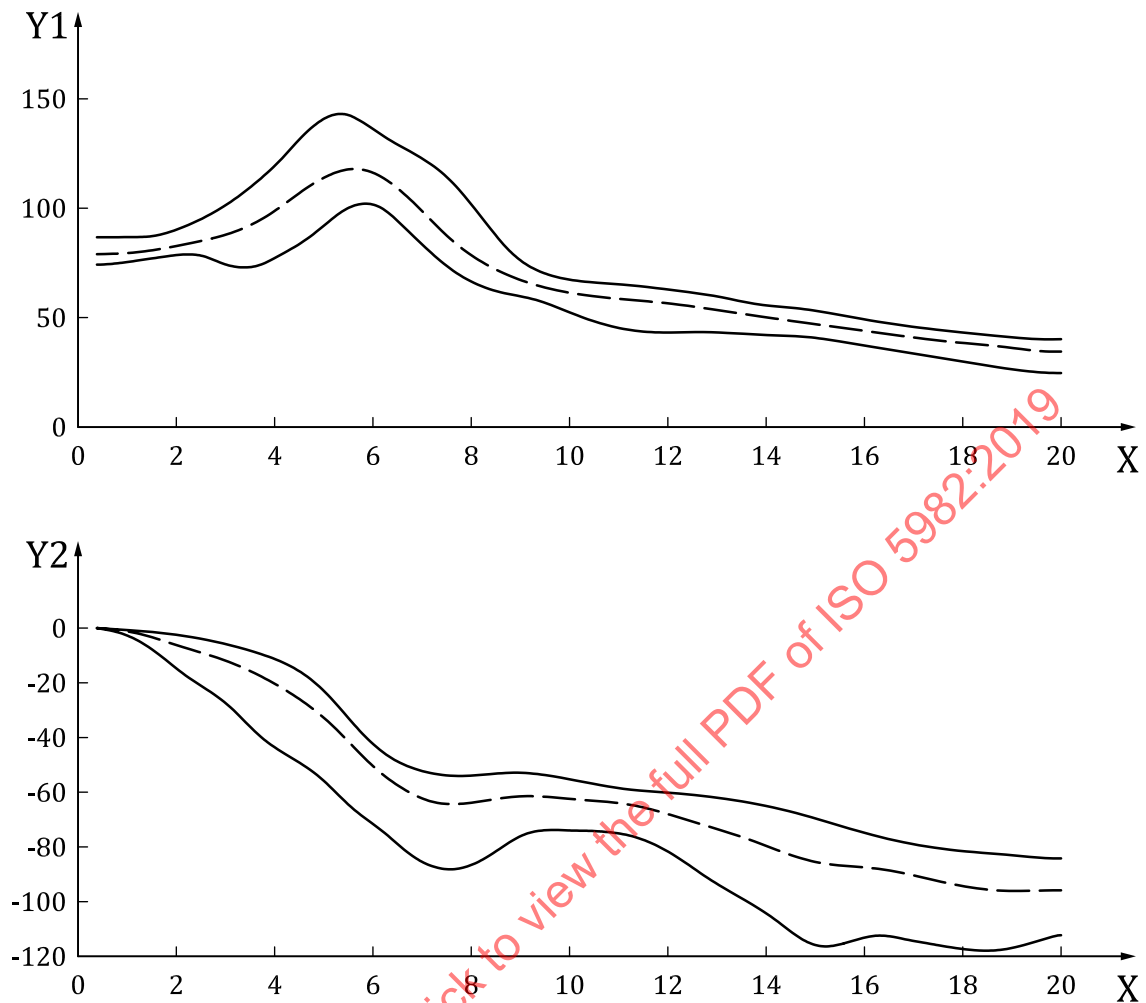
4.8 Applicability of values of apparent mass of the standing body under z-axis vibration

The values of apparent mass are applicable to the standing human body on a rigid platform, subjected to sinusoidal or broad-band random vertical vibration. The limits of applicability approximately correspond to the range of measurement conditions over which data were obtained, as follows:

- a) the posture is described as standing upright erect or relaxed;
- b) the mass of the subjects ranges from 63 kg to 102 kg;
- c) the RMS amplitude of unweighted sine and random excitation is between 0,5 m/s² and 1,0 m/s² over the frequency range of 0,5 Hz to 20 Hz.

Table 7 — Modulus and phase of the mean (target) and range of idealized apparent mass of the standing body under z-axis vibration

Frequency Hz	Modulus kg				Phase °			
	Mean	Upper limit	Lower limit	Standard deviation	Mean	Upper limit	Lower limit	Standard deviation
0,5	78,3	86,8	73,5	7,4	-0,1	0,0	-0,3	0,2
0,63	78,3	86,8	73,5	7,4	-0,1	0,0	-0,3	0,2
0,8	79,8	88,6	75,0	7,6	-0,2	0,0	-0,4	0,2
1	79,8	87,1	75,7	6,4	-0,4	-0,2	-0,6	0,2
1,25	80,0	85,7	76,3	5,0	-1,6	-1,0	-2,7	1,0
1,6	81,2	87,3	77,3	5,3	-4,4	-1,7	-9,4	4,3
2	82,3	90,5	78,2	5,8	-6,3	-2,2	-15,3	6,4
2,5	86,1	95,3	81,6	6,2	-8,7	-3,8	-21,0	8,2
3,15	88,3	103,4	71,5	11,7	-12,3	-6,0	-28,8	11,1
4	99,3	120,3	77,4	15,8	-20,6	-11,2	-44,9	16,2
5	114,7	142,0	92,3	18,8	-33,1	-23,3	-56,1	15,5
6,3	111,0	131,9	97,1	14,4	-55,2	-46,4	-76,5	14,3
8	79,1	99,9	67,0	12,8	-63,3	-53,6	-84,8	14,5
10	61,9	68,3	52,1	6,4	-62,4	-55,6	-74,5	8,6
12,5	54,7	60,8	43,1	7,2	-71,5	-61,7	-89,2	12,2
16	43,8	49,0	36,5	5,6	-88,2	-74,5	-114,2	18,2
20	36,4	41,5	27,0	6,2	-95,5	-82,9	-115,9	15,1

**Key**

X frequency in Hz

Y1 modulus in kg

Y2 phase in °

NOTE For an explanation of the curves, see [4.1](#).

Figure 7 — Mean (target) and range of idealized values for the apparent mass of the standing body under z-axis vibration

5 Seat-to-head transmissibility of the seated human body under vertical vibration

5.1 Definition of values of seat-to-head transmissibility

The modulus and phase of the seat-to-head transmissibility of the seated body are given in [Table 8](#) and (for illustration) in [Figure 8](#) as a function of frequency, for the vertical direction of excitation. In accordance with the definition, the modulus is non-dimensional and represents the ratio of acceleration transmitted to the head to the acceleration measured at the buttocks. The table and diagram contain three values of modulus and phase at each frequency. Numerical values are quoted up to four significant figures for the purpose of calculation, and do not reflect the precision of knowledge of the seat-to-head transmissibility. Linear interpolation is permitted to obtain values at frequencies other than those listed in [Table 8](#) at one-third-octave band centre frequencies.

The upper and lower limiting values at each one-third-octave band centre frequency encompass the mean values of all data sets selected, and are shown by continuous curves in Figure 8. The central value at each frequency, shown by dashed curves in Figure 8, provides an estimate of the weighted mean of all data sets selected, and forms the target value for all applications. The standard deviations computed with respect to the weighted mean (target) values are also listed in Table 8.

Applications shall generate/employ values of seat-to-head transmissibility between the upper and lower limits given in Table 8 at any frequency, and represent “through the body” transfer functions applicable to the seated human body under the conditions specified and over the frequency range of 0,5 Hz to 20 Hz.

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

Table 8 — Modulus and phase of the mean (target) and range of idealized seat-to-head transmissibility of the seated body under z-axis vibration

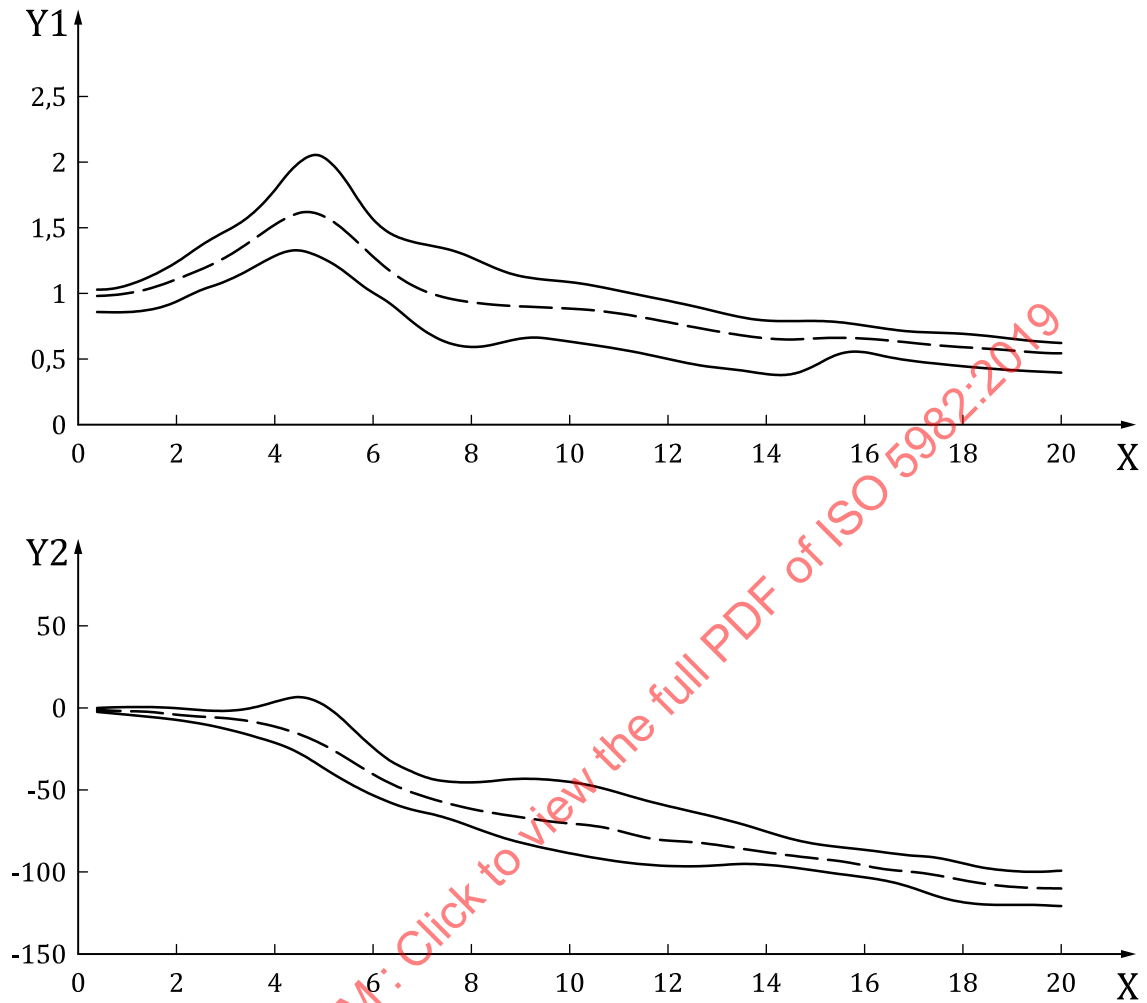
Frequency Hz	Modulus				Phase °			
	Mean	Upper limit	Lower limit	Standard deviation	Mean	Upper limit	Lower limit	Standard deviation
0,5	0,97	1,02	0,87	0,06	0,0	0,0	-0,1	0,01
0,63	0,98	1,02	0,87	0,06	-0,1	-0,1	-0,1	0,02
0,8	0,98	1,03	0,87	0,06	-1,5	-0,1	-3,0	2,1
1	1,00	1,04	0,86	0,07	-1,7	0,0	-5,0	2,9
1,25	1,02	1,09	0,86	0,08	-2,7	-0,1	-6,0	3,0
1,6	1,06	1,15	0,87	0,10	-3,2	-0,2	-6,3	3,1
2	1,10	1,24	0,93	0,11	-4,2	-0,2	-7,8	3,8
2,5	1,19	1,38	1,04	0,12	-5,2	-1,1	-10,1	4,1
3,15	1,30	1,50	1,10	0,15	-6,4	-2,6	-13,8	5,1
4	1,54	1,80	1,31	0,19	-11,8	4,3	-21,1	11,5
5	1,59	2,05	1,26	0,27	-23,4	1,8	-37,7	18,1
6,3	1,18	1,47	0,92	0,22	-45,6	-31,3	-57,6	12,4
8	0,94	1,27	0,61	0,25	-61,9	-44,9	-73,2	12,6
10	0,88	1,08	0,62	0,17	-71,3	-46,7	-88,8	17,9
12,5	0,74	0,90	0,47	0,17	-82,7	-64,1	-95,9	14,0
16	0,64	0,75	0,48	0,11	-97,0	-87,1	-105,7	9,1
20	0,57	0,66	0,42	0,11	-108,2	-98,3	-119,7	9,9

5.2 Applicability of values of seat-to-head transmissibility

The values of seat-to-head transmissibility are applicable to the seated human body subjected to sinusoidal or broad-band random vertical vibration, while seated on a rigid surface with the back being unsupported. Both conditions of feet being supported on a vibrating platform and hanging freely are integrated for the purpose of defining seat-to-head transmissibility. The limits of applicability approximately correspond to the range of measurement conditions over which data were obtained, as follows:

- the posture is described as erect seated without backrest support, while the feet may be supported or not;
- the mass of the subjects ranges from 58 kg to 99 kg;

- c) the RMS amplitude of unweighted sine and random excitation is between $1,0 \text{ m/s}^2$ and $2,8 \text{ m/s}^2$ over the frequency range of 0,5 Hz to 20 Hz.



Key

X frequency in Hz

Y1 modulus

Y2 phase in °

NOTE For an explanation of the curves, see [5.1](#).

Figure 8 — Mean (target) and range of idealized values for the seat-to-head transmissibility of the seated body under z-axis vibration

Annex A (informative)

Identification of the data used to define the range of idealized apparent mass and seat-to-head transmissibility

A set of selection rules are defined for selecting the published data to be used for the synthesis^[36]. Only those data sets satisfying all of the following conditions were considered:

- a) data sets reporting either the magnitude or the magnitude and phase of the biodynamic response function;
- b) data sets derived using adult subjects with body mass ranging from approximately 55 kg to 110 kg;
- c) data sets reported under either sinusoidal or random vibration within the 0.5 Hz to 20 Hz frequency range for the vertical direction, while those for the horizontal direction were limited up to 10 Hz;
- d) data sets acquired under vibration of unweighted RMS magnitude lower than or equal to 2 m/s²;
- e) data sets acquired with clearly defined subject while those reporting a single subject data were carefully examined;
- f) head acceleration data for seat-to-head transmissibility were acquired using an accelerometer positioned either on a bite-bar or at the top of the skull.

A set of rejection criteria has been added:

- 1) data sets with unsupported feet (for data involving apparent mass/driving-point mechanical impedance only), with feet not vibrated or with the feet condition not clearly identified;
- 2) data sets involving children;
- 3) data sets for automotive posture;
- 4) data sets not reporting the total body mass;
- 5) studies involving only one subject, except for the standing body posture, where the number of available data sets is limited;
- 6) studies where the mean response could not be obtained from individual data;
- 7) studies reporting response at a few discrete frequencies;
- 8) data sets that are considered outliers (large variation in the standard deviation of the idealized apparent mass magnitude or phase when the outlier is removed from the data set).

[Tables A.1](#) to [A.7](#) identify the data sets considered for driving-point mechanical impedance and apparent mass, while [Table A.8](#) identifies those considered for seat-to-head transmissibility. References to these data sets are given in the Bibliography.

Table A.1 — Characterization of the data sets considered for mechanical impedance and apparent mass of the seated body in the fore-aft direction (x-axis) — With a back support

Bibliographic reference	Subjects		Type	Excitation		Reported function
	Number (gender)	Mass (mean) kg		Amplitude	Frequency range Hz	
[6] – vb	8 (M)	57 to 85 (65,7)	Random	1,0 m/s ² RMS unweighted	0,25 to 20	Mean apparent mass Modulus and phase
[16] – vb	8 (M)	59 to 92 (71,2)	Random	0,5 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase
[16] – ib	8 (M)	59 to 92 (71,2)	Random	0,5 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase
[16] – vb	8 (M)	59 to 92 (71,2)	Random	1,0 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase
[16] – ib	8 (M)	59 to 92 (71,2)	Random	1,0 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase

NOTE vb – vertical back support; ib – inclined back support.

Table A.2 — Characterization of the data sets considered for mechanical impedance and apparent mass of the seated body in the fore-aft direction (x-axis) — No back support

Bibliographic reference	Subjects		Type	Excitation		Reported function
	Number (gender)	Mass (mean) kg		Amplitude	Frequency range Hz	
[6]	8 (M)	57 to 85 (65,7)	Random	0,5 m/s ² RMS unweighted	0,25 to 20	Mean apparent mass Modulus and phase
[6]	8 (M)	57 to 85 (65,7)	Random	1,0 m/s ² RMS unweighted	0,25 to 20	Mean apparent mass Modulus
[11]	15 (M)	55 to 93 (75)	Sinusoidal	1,0 m/s ² RMS unweighted	1,13 to 80	Mean mechanical impedance Modulus
[17]	15 (M)	NR (75,8)	Random	1,0 m/s ² RMS unweighted	1,5 to 20	Median apparent mass Phase
[13]	15 (M)	55 to 93 (75)	Sinusoidal	1,0 m/s ² RMS unweighted	2 to 100	Mean mechanical impedance Modulus and phase
[16]	8 (M)	59 to 92 (71,2)	Random	0,5 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase
[16]	8 (M)	59 to 92 (71,2)	Random	1,0 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase

Table A.2 (continued)

Bibliographic reference	Subjects		Type	Excitation		Reported function
	Number (gender)	Mass (mean) kg		Amplitude	Frequency range Hz	
[33]	12 (M)	56 to 87 (77,5)	Random	1,0 m/s ² RMS unweighted	0,25 to 20	Median apparent Modulus and phase
[9]	13 (M)	61,3 to 103,6 (79,3)	Random	1,0 m/s ² RMS unweighted	0,25 to 30	Mean apparent mass Modulus
[24]	15 (M)	NR (64,3)	Random	0,8 m/s ² RMS unweighted	1 to 20	Median apparent mass Modulus

Table A.3 — Characterization of the data sets considered for mechanical impedance and apparent mass of the seated body in the lateral direction (y-axis) — With a back support

Bibliographic reference	Subjects		Type	Excitation		Reported function
	Number (gender)	Mass (mean) kg		Amplitude	Frequency range Hz	
[6] – vb	8 (M)	57 to 85 (65,7)	Random	1,0 m/s ² RMS unweighted	0,25 to 20	Mean apparent mass Modulus and phase
[16] – vb	8 (M)	59 to 92 (71,2)	Random	0,5 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase
[16] – ib	8 (M)	59 to 92 (71,2)	Random	0,5 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase
[16] – vb	8 (M)	59 to 92 (71,2)	Random	1,0 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase
[16] – ib	8 (M)	59 to 92 (71,2)	Random	1,0 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase
[22] – vb	15 (M)	NR (64,3)	Random	0,4 m/s ² RMS unweighted	1 to 20	Median apparent mass Modulus

NOTE vb – vertical back support; ib – inclined back support.

Table A.4 — Characterization of the data sets considered for mechanical impedance and apparent mass of the seated body in the lateral direction (y-axis) — No back support

Bibliographic reference	Subjects		Type	Excitation		Reported function
	Number (gender)	Mass (mean) kg		Amplitude	Frequency range Hz	
[6]	8 (M)	57 to 85 (65,7)	Random	0,5 m/s ² RMS unweighted	0,25 to 20	Mean apparent mass Modulus and phase
[6]	8 (M)	57 to 85 (65,7)	Random	1,0 m/s ² RMS unweighted	0,25 to 20	Mean apparent mass Modulus
[11]	15 (M)	55 to 93 (75)	Sinusoidal	1,0 m/s ² RMS unweighted	1,13 to 80	Mean mechanical impedance Modulus and phase

Table A.4 (continued)

Bibliographic reference	Subjects		Type	Excitation		Reported function
	Number (gender)	Mass (mean) kg		Amplitude	Frequency range Hz	
[17]	15 (M)	NR (75,8)	Random	1,0 m/s ² RMS unweighted	1,5 to 20	Median apparent mass Phase
[13]	15 (M)	55 to 93 (75)	Sinusoidal	1,0 m/s ² RMS unweighted	2 to 100	Mean mechanical impedance Modulus and phase
[16]	8 (M)	59 to 92 (71,2)	Random	0,5 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase
[16]	8 (M)	59 to 92 (71,2)	Random	1,0 m/s ² RMS unweighted	0,5 to 10	Mean apparent mass Modulus and phase
[9]	13 (M)	61,3 to 103,6 (79,3)	Random	1,0 m/s ² RMS unweighted	0,25 to 30	Mean apparent mass Modulus

Table A.5 — Characterization of the data sets considered for mechanical impedance and apparent mass of the seated body in the vertical direction (z-axis) — With a back support

Bibliographic reference	Subjects		Type	Excitation		Function considered
	Number (gender)	Mass (mean) kg		Amplitude	Frequency range Hz	
[1] – vb	6 (M)	70 to 81 (75,4)	Random	1,0 m/s ² RMS unweighted	0,625 to 10	Mean mechanical impedance Modulus and phase
[20] – vb	12 (M)	NR (75,4)	Random	1,0 m/s ² RMS unweighted	1 to 20	Individual normalized apparent mass Modulus
[31] – vb	12 (M)	62 to 106 (77,2)	Random	0,625 m/s ² RMS unweighted	0,25 to 20	Median apparent mass Modulus
[41] – vb	4 (M)	NR (70)	Random	1,0 m/s ² RMS unweighted	0,5 to 40	Mean mechanical impedance Modulus and phase
[41] – vb	7 (M)	70,5 to 80 (75,1)	Random	1,0 m/s ² RMS unweighted	0,5 to 40	Mean mechanical impedance Modulus and phase
[41] – ib 12°	4 (M)	NR (70)	Random	1,0 m/s ² RMS unweighted	0,5 to 40	Mean mechanical impedance Modulus and phase
[41] – ib 12°	7 (M)	70,5 to 80 (75,1)	Random	1,0 m/s ² RMS unweighted	0,5 to 40	Mean mechanical impedance Modulus and phase

NOTE vb – vertical back support; ib – inclined back support.

Table A.5 (continued)

Bibliographic reference	Subjects		Type	Excitation		Function considered
	Number (gender)	Mass (mean) kg		Amplitude	Frequency range Hz	
[32] – vb	12 (M)	62 to 106 (77,2)	Random	0,625 m/s ² RMS unweighted	0,25 to 20	Median apparent mass Modulus
[24] – vb	15 (M)	NR (64,3)	Random	0,8 m/s ² RMS unweighted	1 to 20	Median apparent mass Modulus
[35] – ib 12°	9 (M)	50 to 60 (55,7)	Random	1,0 m/s ² RMS unweighted	0,5 to 20	Mean apparent mass Phase
[35] – ib 12°	9 (M)	70 to 80 (75,2)	Random	1,0 m/s ² RMS unweighted	0,5 to 20	Mean apparent mass Modulus and phase
[35] – ib 12°	9 (M)	93 to 107 (98)	Random	1,0 m/s ² RMS unweighted	0,5 to 20	Mean apparent mass Phase
[42] – vb	12 (M)	66,4 to 99,6 (77,3)	Random	1,0 m/s ² RMS unweighted	0,5 to 15	Mean apparent mass Modulus and phase
[42] – ib 12°	12 (M)	66,4 to 99,6 (77,3)	Random	1,0 m/s ² RMS unweighted	0,5 to 15	Mean apparent mass Modulus and phase

NOTE vb – vertical back support; ib – inclined back support.

Table A.6 — Characterization of the data sets considered for mechanical impedance and apparent mass of the seated body in the vertical direction (z-axis) — No back support

Bibliographic reference	Subjects		Type	Excitation		Function considered
	Number (gender)	Mass (mean) kg		Amplitude	Frequency range Hz	
[37]	6 (M)	52,7 to 87,2	Random	1,0 m/s ² RMS unweighted	1 to 25	Individual apparent mass Modulus and phase
[3]	15 (M)	49 to 74 (62,9)	Random	1,6 m/s ² RMS unweighted	1 to 10	Mean mechanical impedance Modulus
[3]	15 (M)	49 to 74 (62,9)	Sinusoidal	1,6 m/s ² RMS unweighted	1 to 10	Mean mechanical impedance Modulus and phase
[5]	8 (M)	57 to 85 (71,8)	Random	1,0 m/s ² RMS unweighted	0,25 to 20	Individual apparent mass Modulus and phase
[7]	4 (M)	56 to 83 (71,2)	Sinusoidal	1,5 m/s ² RMS unweighted	2 to 12	Mean apparent mass Phase
[7]	4 (M)	56 to 83 (71,2)	Sinusoidal	3,0 m/s ² RMS unweighted	2 to 12	Mean apparent mass Phase

Table A.6 (continued)

Bibliographic reference	Subjects		Type	Excitation		Function considered
	Number (gender)	Mass (mean) kg		Amplitude	Frequency range Hz	
[10]	15 (M) 15 (F)	55 to 92 (74) 54 to 93 (66)	Sinusoidal	0,5 m/s ² RMS unweighted	2 to 100	Mean normalized mechanical impedance Modulus and phase
[38]	11 (M)	60 to 70	Random	≤1,4 m/s ² weighted (ISO 2631-1:1985)	0,5 to 20	Mean mechanical impedance Modulus
[38]	14 (M)	70 to 80	Random	≤1,4 m/s ² weighted (ISO 2631-1:1985)	0,5 to 20	Mean mechanical impedance Modulus
[43]	6 (M)	58 to 73 (64,2)	Random	1,0 m/s ² RMS unweighted	0,5 to 20	Mean apparent mass Modulus and phase
[1]	6 (M)	70 to 81 (75,4)	Random	1,0 m/s ² weighted (ISO 2631-1:1985)	0,625 to 10	Mean mechanical impedance Modulus and phase
[1]	6 (M)	70 to 81 (75,4)	Sinusoidal	1,0 m/s ² weighted (ISO 2631-1:1985)	0,625 to 10	Mean mechanical impedance Modulus and phase
[12] “Erect posture”	15 (M) 15 (F)	55 to 92 (74) 54 to 93 (66)	Sinusoidal	1,4 m/s ² RMS unweighted	2 to 100	Mean mechanical impedance Modulus and phase
[12] “Relaxed posture”	15 (M) 15 (F)	55 to 92 (74) 54 to 93 (66)	Sinusoidal	1,4 m/s ² RMS unweighted	2 to 100	Mean mechanical impedance Modulus and phase
[18]	12 (M)	60 to 85 (68,3)	Random	1,0 m/s ² RMS unweighted	2 to 20	Median normalized apparent mass Modulus
[30]	12 (M)	57 to 106 (74,6)	Random	1,25 m/s ² RMS unweighted	0,25 to 25	Median apparent mass Modulus and phase
[20]	12 (M)	NR (75,4)	Random	1,0 m/s ² RMS unweighted	1 to 20	Individual normalized apparent mass Modulus
[19]	11 (M) 13 (F)	72 to 96 (81) 54 to 79 (67)	Random	1,0 m/s ² RMS unweighted	2 to 20	Median apparent mass Modulus
[27]	8 (M)	64 to 87 (73)	Random	1,0 m/s ² RMS unweighted	2 to 20	Median normalized apparent mass Modulus and phase
[41]	4 (M)	NR (70)	Random	1,0 m/s ² RMS unweighted	0,5 to 40	Mean apparent mass Modulus and phase
[41]	7 (M)	70,5 to 80 (75,1)	Random	1,0 m/s ² RMS unweighted	0,5 to 40	Mean apparent mass Modulus and phase

Table A.6 (continued)

Bibliographic reference	Subjects		Type	Excitation		Function considered
	Number (gender)	Mass (mean) kg		Amplitude	Frequency range Hz	
[15]	12 (M)	NR (65,8)	Random	1,0 m/s ² RMS unweighted	1 to 20	Median apparent mass Modulus and phase
[21]	12 (M)	NR (65,8)	Random	1,0 m/s ² RMS unweighted	1 to 40	Median normalized apparent mass Modulus
[40]	5 (M)	89,8 to 98,7 (80,7)	Random	1,0 m/s ² RMS unweighted	1 to 50	Mean apparent mass Modulus
[44]	14 (M)	NR (70,3)	Random	2,0 m/s ² RMS unweighted	0,5 to 20	Median normalized apparent mass Modulus
[9]	13 (M)	61,3 to 103,6 (79,3)	Random	1,0 m/s ² RMS unweighted	0,25 to 30	Mean apparent mass Modulus
[23]	12 (M)	NR (79,1)	Random	1,0 m/s ² RMS unweighted	2 to 20	Median apparent mass Modulus
[24]	15 (M)	NR (64,3)	Random	0,8 m/s ² RMS unweighted	1 to 20	Median apparent mass Modulus
[35]	9 (M)	50 to 60 (55,7)	Random	1,0 m/s ² RMS unweighted	0,5 to 20	Mean apparent mass Phase
[35]	9 (M)	70 to 80 (75,2)	Random	1,0 m/s ² RMS unweighted	0,5 to 20	Mean apparent mass Modulus and phase
[35]	9 (M)	93 to 107 (98)	Random	1,0 m/s ² RMS unweighted	0,5 to 20	Mean apparent mass Phase
[42]	12 (M)	66,4 to 99,6 (77,3)	Random	1,0 m/s ² RMS unweighted	0,5 to 15	Mean apparent mass Modulus and phase

Table A.7 — Characterization of the data sets considered for mechanical impedance and apparent mass of the standing body in the vertical direction (z-axis)

Bibliographic reference	Subjects		Type	Excitation	Frequency range Hz	Reported function
	Number (gender)	Mass (mean) kg		Amplitude		
[2]	1 (M)	84	Sinusoidal	≤0,5 g peak unweighted	1 to 20	Mechanical impedance Modulus
[4]	2 (M)	77,7 and 84 (81)	Sinusoidal	0,2 g peak unweighted	1 to 20	Mechanical impedance Phase (individual)
[29]	20 (M)	50 to 76 ^a (59)	Sinusoidal	0,1 g peak unweighted	3 to 200	Mean mechanical impedance Modulus
[25]	12 (M)	Median (73,5)	Random	1,0 m/s ² RMS unweighted	0,5 to 30	Median normalized apparent mass Modulus and phase
[26]	8 (M)	63 to 83 ^b (72)	Random	1,0 m/s ² RMS unweighted	0,5 to 20	Median normalized apparent mass Modulus and phase
[39]	12 (M)	65,6 to 102 (77,5)	Random	0,5 m/s ² RMS unweighted	0,5 to 20	Median apparent mass Modulus and phase

^a Body mass range of 5 subjects.

^b Body mass range estimated from individuals' data.

Table A.8 — Characterization of the data sets considered for seat-to-head transmissibility (STHT) of the seated body in the vertical direction (z-axis)

Bibliographic reference	Subjects		Type	Excitation	Frequency range Hz	Reported function
	Number (gender)	Mass (mean) kg		Amplitude		
[28]	6 (M) 3 (F)	57 to 90	Sinusoidal	4,85 m/s ² RMS unweighted	2 to 20	Mean modulus and phase
[34]	12 (M)	58 to 81 (70,8)	Random	1,75 m/s ² RMS unweighted	Up to 25 Hz	Individual modulus; phase (n = 1; 80 kg)
[14]	8 (M)	(74,6)	Random	1,7 m/s ² RMS unweighted	0,5 to 35	Mean modulus
[43]	6 (M)	58 to 73 (64,2)	Random	1,0 m/s ² RMS unweighted	0,625 to 20	Mean modulus and phase
[8]	39 (M)	NR	Random; (1-4 Hz)	1,0 m/s ² RMS weighted	1 to 20	Mean phase (hands on steering wheel)
[40]	5 (M)	65,7 to 98,7	Random	1,0 m/s ² RMS unweighted	1 to 50	Mean modulus
[42]	12 (M)	66,4 to 99,6 (77,3)	Random	1,0 m/s ² RMS unweighted	0,5 to 15	Median modulus

Annex B
(informative)

Lumped mass model

The model (see [Figure B.1](#)) constitutes a three-degrees-of-freedom system for which the masses, springs and dampers do not correspond to physiological structures within the body. The input force is considered to be applied to mass m_0 for which the resulting displacement is represented by x_0 . The model parameters listed in [Table B.1](#) were derived to obtain agreement with the weighted mean (target) values defined for the apparent mass in the vertical direction with no back support and the seat-to-head transmissibility as given in [Tables 6](#) and [8](#). The model predictions are illustrated by dashed lines in [Figures B.2](#) and [B.3](#) where they are compared with the range of idealized values defined respectively for the apparent mass and the seat-to-head transmissibility. The model parameters listed in [Table B.1](#) would most likely apply to a subject with total body mass of 75 kg, while assuming that 73 % of the mass is resting on the seat. For the purpose of computing seat-to-head transmissibility, mass m_2 may tentatively be taken to represent the head.

Table B.1 — Values of the parameters of the model (body mass of 75 kg)

Parameter	Mass				Stiffness			Damping coefficient		
	kg				N/m			N×s/m		
	m_0	m_1	m_2	m_3	k_1	k_2	k_3	c_1	c_2	c_3
Value	2	6	2	45	$9,99 \times 10^3$	$3,44 \times 10^4$	$3,62 \times 10^4$	387	234	$1,39 \times 10^3$

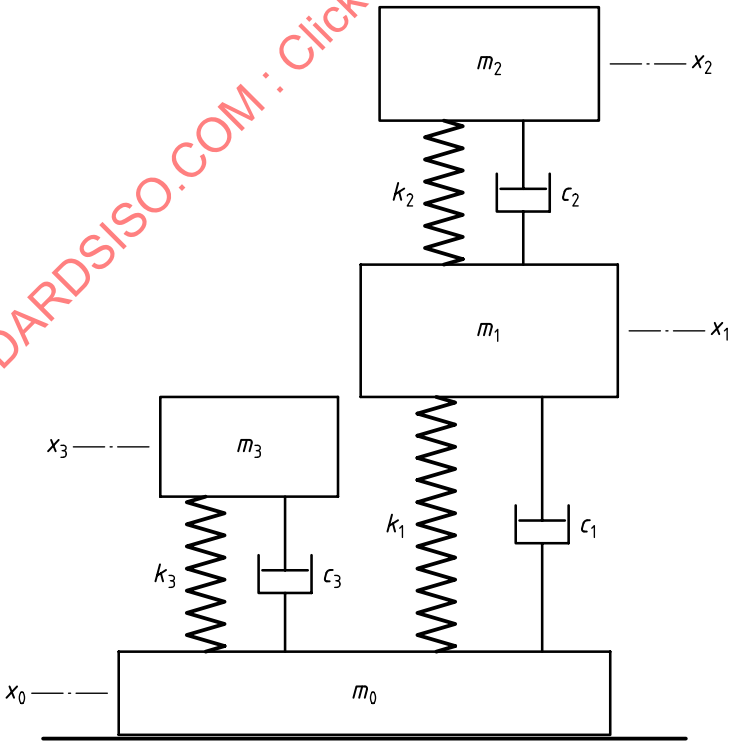
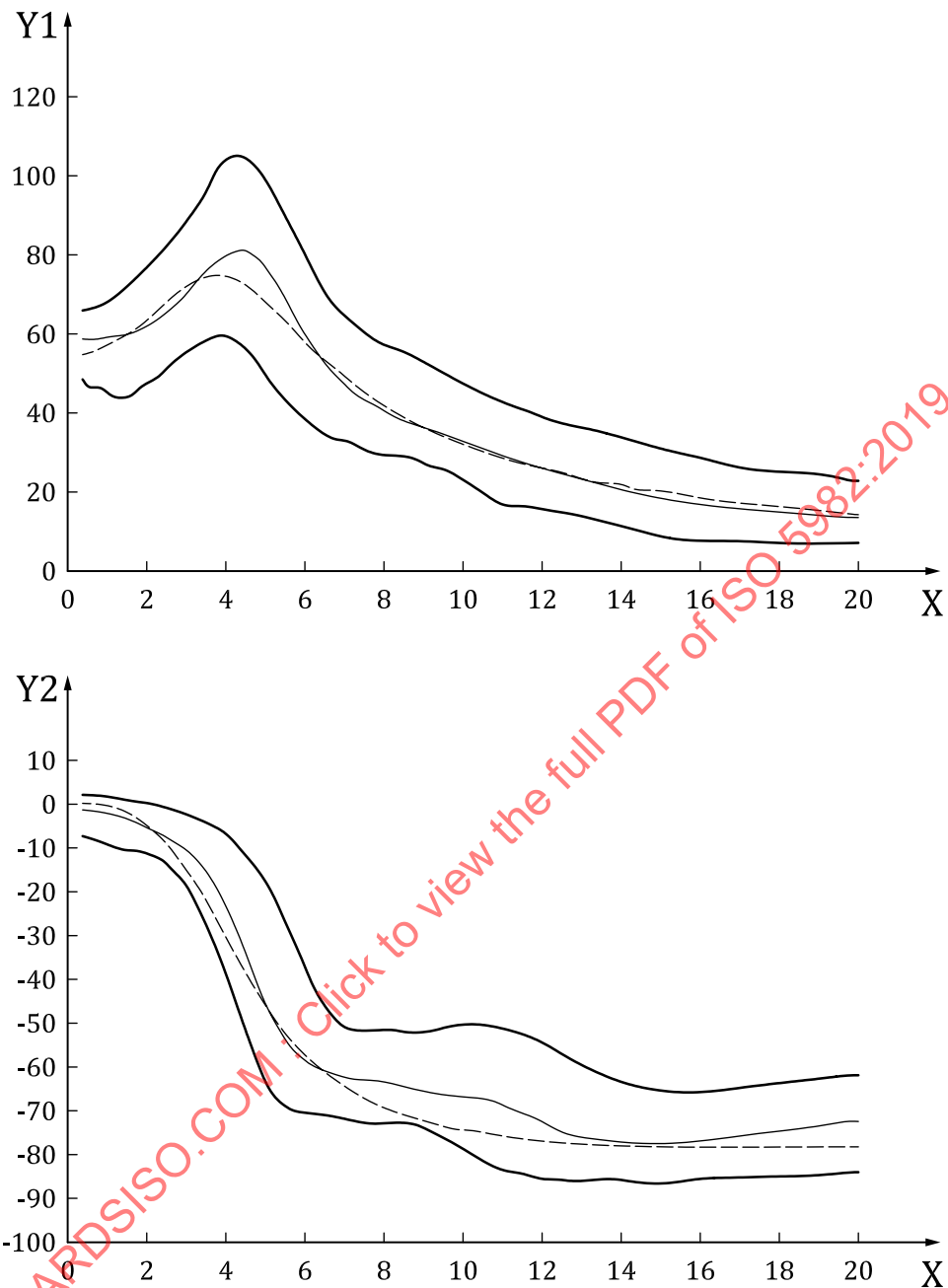


Figure B.1 — Biodynamic model of the seated human body

**Key**

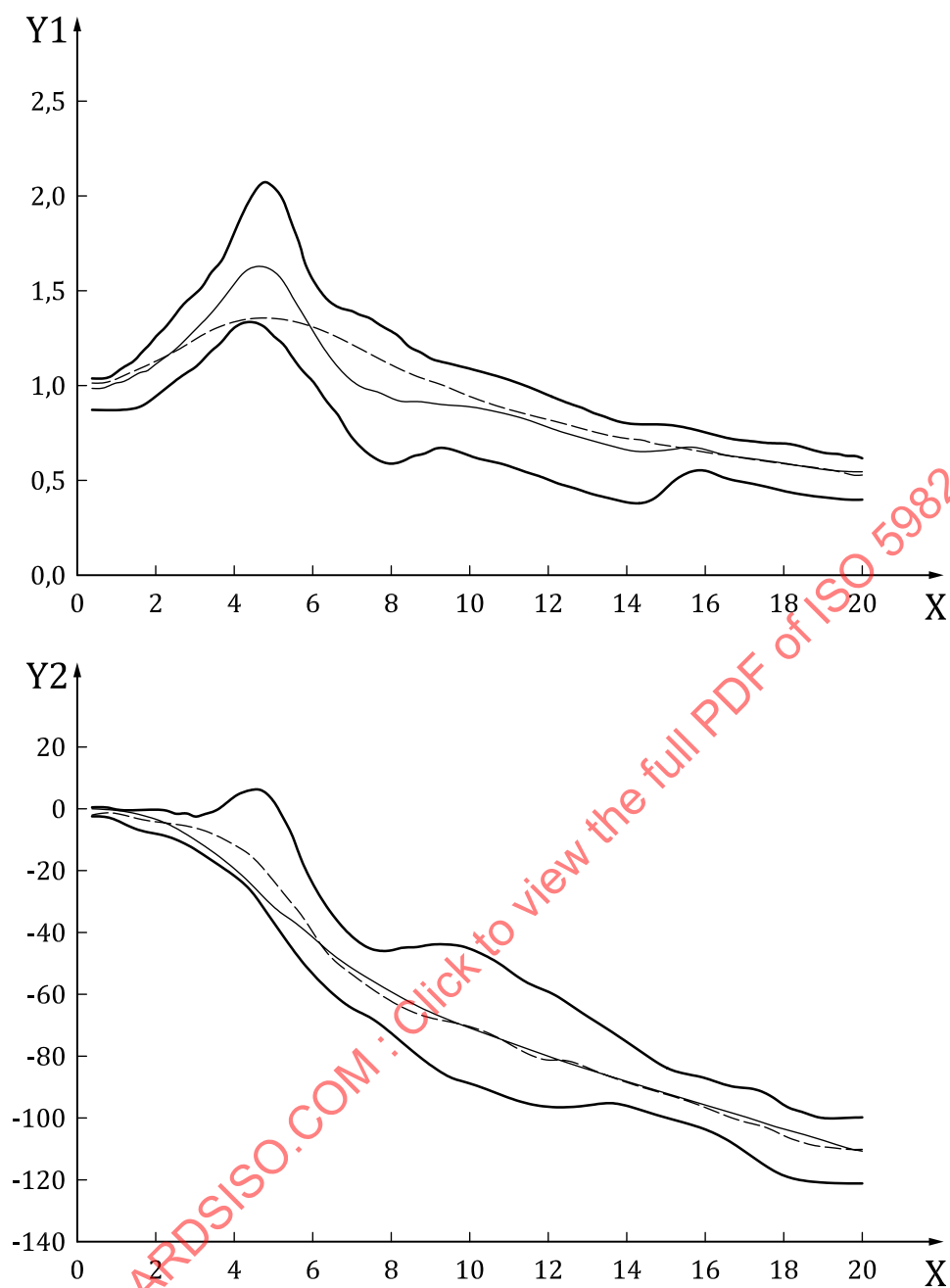
X frequency in Hz

Y1 modulus in kg

Y2 phase in °

NOTE For an explanation of the curves, see [4.1](#).

Figure B.2 — Comparison between model (dashed line) predictions and the range of idealized values for the vertical apparent mass with no back support



Key

X frequency in Hz

Y1 modulus

Y2 phase in °

NOTE For an explanation of the curves, see [5.1](#).

Figure B.3 — Comparison between model (dashed line) predictions and the range of idealized values for the seat-to-head transmissibility

Annex C (informative)

Mathematical models

Mathematical expressions in the form of transfer functions denoted by $H(s)$ are defined to approximate the mean (target) values defined at each frequency in [Figures 1](#) to [7](#) for the apparent mass and in [Figure 8](#) for the seat-to-head transmissibility. The coefficients of the transfer functions are given in [Tables C.1](#) to [C.8](#) for $H(s)$. The computed responses resulting from these formulae are illustrated by dotted lines in [Figures C.1](#) to [C.8](#) where they are compared with the mean and range of idealized values defined respectively for the apparent mass and the seat-to-head transmissibility.

$H(s)$ is given by [Formula \(C.1\)](#):

$$H(s) = K \cdot \frac{P(s)}{Q(s)} \quad (\text{C.1})$$

where

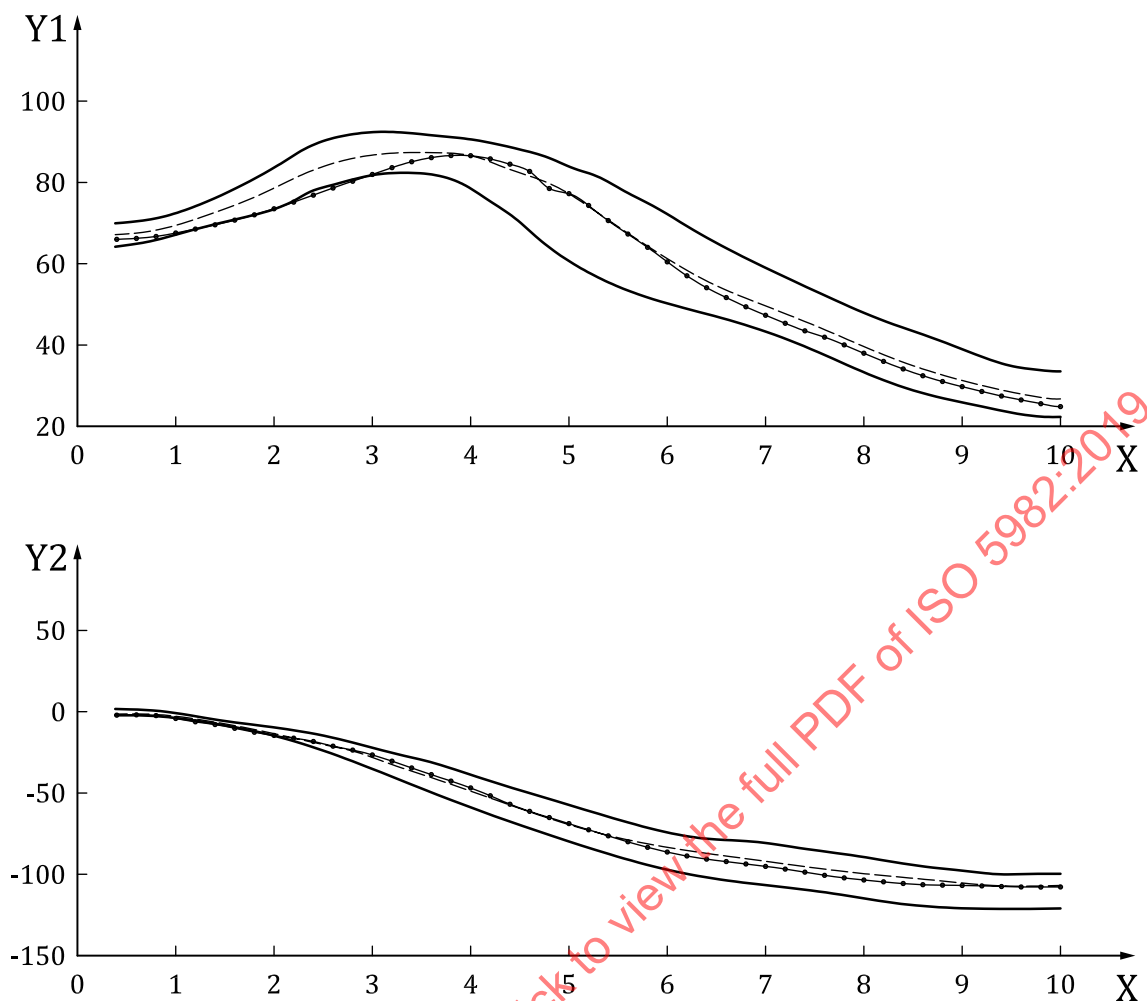
$$P(s) = (s^2 + A_1 \cdot s + B_1) \cdot (s^2 + A_2 \cdot s + B_2) \cdot (s^2 + A_3 \cdot s + B_3)$$

$$Q(s) = (s^2 + C_1 \cdot s + D_1) \cdot (s^2 + C_2 \cdot s + D_2) \cdot (s^2 + C_3 \cdot s + D_3) \cdot (s^2 + C_4 \cdot s + D_4)$$

$$s = 2\pi j f \quad j = \sqrt{-1}$$

Table C.1 — Coefficients of the transfer function for the apparent mass of the seated body with a back support under x-axis vibration

Coefficient	$H(s)$	Coefficient	$H(s)$
K	$5,875 \times 10^4$	C_1	$2,702 \times 10^1$
A_1	$5,542 \times 10^2$	D_1	$9,106 \times 10^2$
B_1	$3,950 \times 10^4$	C_2	$2,658 \times 10^{-2}$
A_2	$2,572 \times 10^{-2}$	D_2	$9,085 \times 10^2$
B_2	$9,085 \times 10^2$	C_3	$1,038 \times 10^1$
A_3	$1,110 \times 10^1$	D_3	$2,274 \times 10^3$
B_3	$2,263 \times 10^3$	C_4	3,400
		D_4	$3,853 \times 10^4$

**Key**

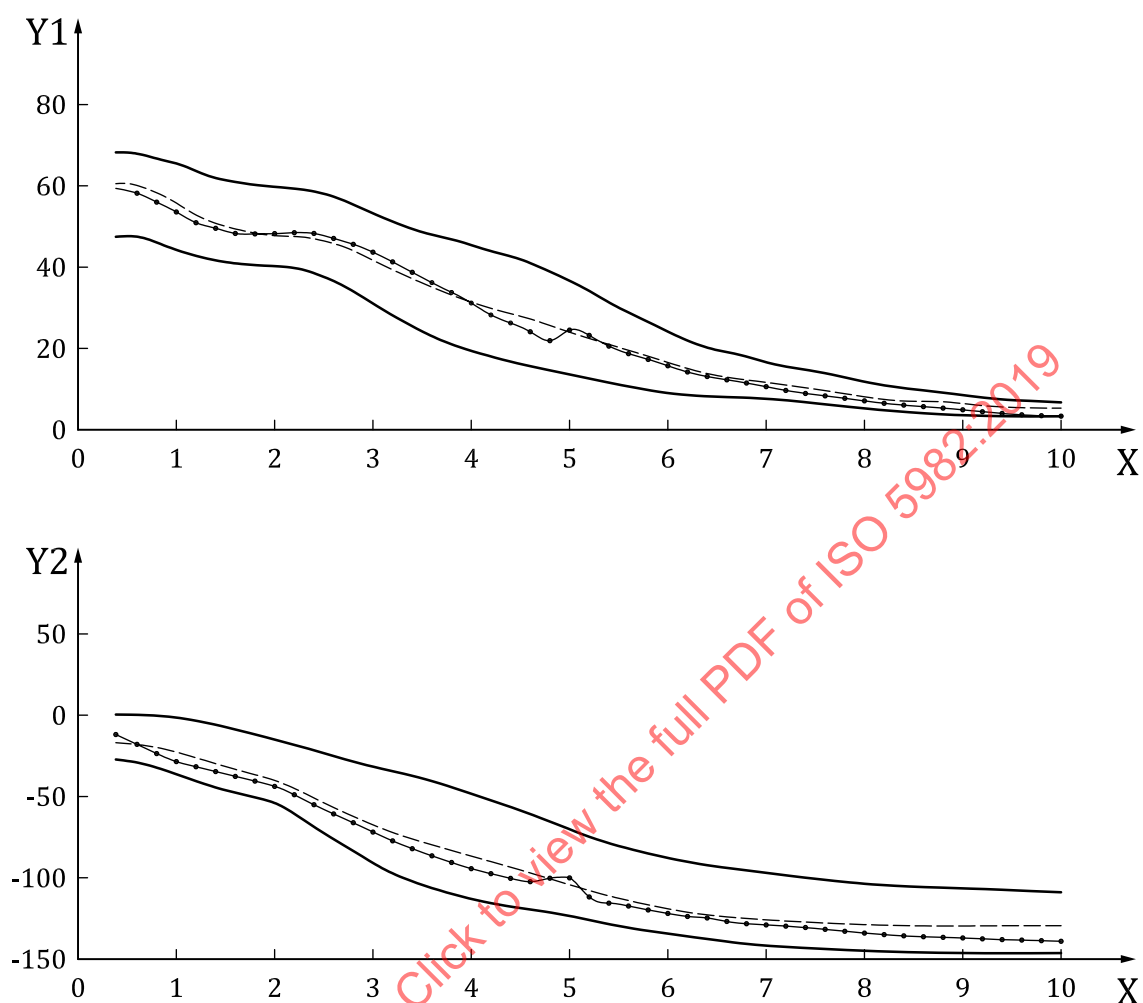
X frequency in Hz

Y1 modulus in kg

Y2 phase in °

NOTE For an explanation of the curves, see [4.1](#).**Figure C.1 — Comparison between the transfer function (dotted line) and the range of idealized values for the apparent mass of the seated body with a back support under x-axis vibration****Table C.2 — Coefficients of the transfer function for the apparent mass of the seated body without a back support under x-axis vibration**

Coefficient	$H(s)$	Coefficient	$H(s)$
K	$1,441 \times 10^{16}$	C_1	$1,552 \times 10^{10}$
A_1	$1,143 \times 10^1$	D_1	$3,211 \times 10^{15}$
B_1	$1,317 \times 10^2$	C_2	$3,172 \times 10^1$
A_2	2,080	D_2	$3,530 \times 10^2$
B_2	$9,667 \times 10^2$	C_3	$1,592 \times 10^1$
A_3	6,484	D_3	$1,876 \times 10^2$
B_3	$6,941 \times 10^3$	C_4	1,952
		D_4	$9,798 \times 10^2$



Key

X frequency in Hz

Y1 modulus in kg

Y2 phase in °

NOTE For an explanation of the curves, see 4.1.

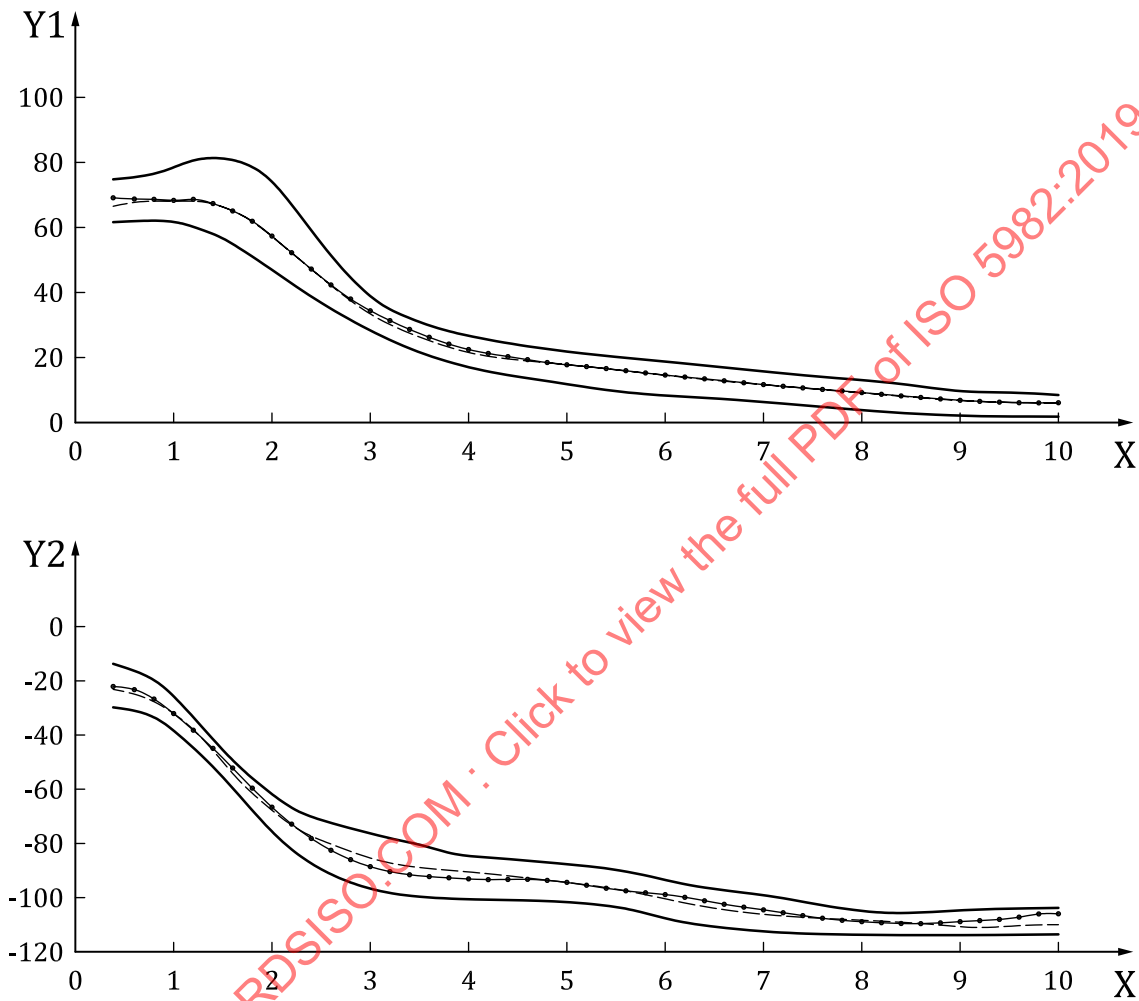
Figure C.2 — Comparison between the transfer function (dotted line) and the range of idealized values for the apparent mass of the seated body without a back support under x-axis vibration

Table C.3 — Coefficients of the transfer function for the apparent mass of the seated body with a back support under y-axis vibration

Coefficient	$H(s)$	Coefficient	$H(s)$
K	$1,196 \times 10^{19}$	C_1	$2,326 \times 10^{16}$
A_1	$1,782 \times 10^1$	D_1	$6,880 \times 10^{12}$
B_1	9,781	C_2	$1,736 \times 10^1$
A_2	$2,761 \times 10^1$	D_2	$1,846 \times 10^2$
B_2	$6,740 \times 10^2$	C_3	$5,406 \times 10^1$

Table C.3 (continued)

Coefficient	$H(s)$	Coefficient	$H(s)$
A_3	$4,645 \times 10^1$	D_3	$8,930 \times 10^2$
B_3	$4,547 \times 10^3$	C_4	$5,233 \times 10^1$
		D_4	$2,465 \times 10^3$



Key

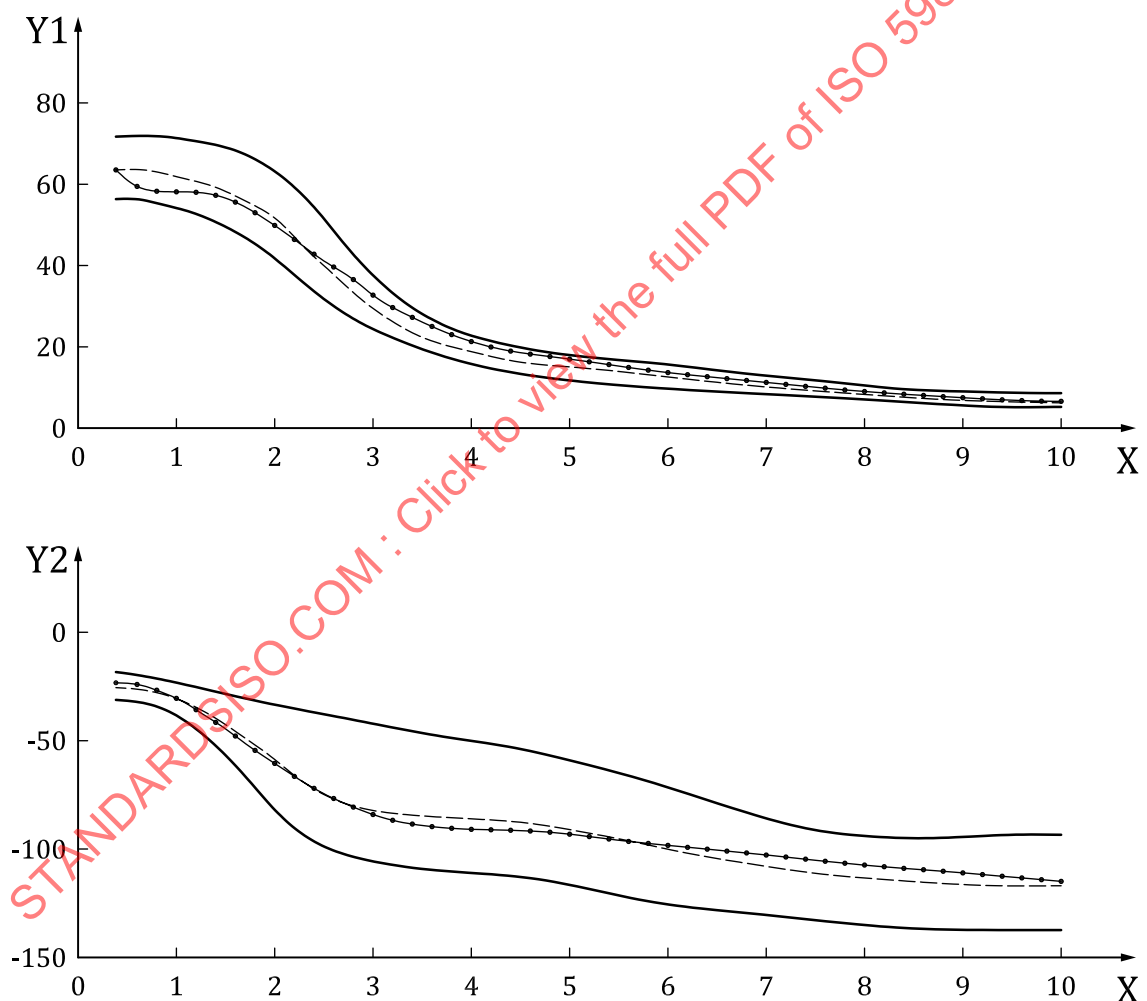
- X frequency in Hz
- Y1 modulus in kg
- Y2 phase in °

NOTE For an explanation of the curves, see 4.1.

Figure C.3 — Comparison between the transfer function (dotted line) and the range of idealized values for the apparent mass of the seated body with a back support under y-axis vibration

Table C.4 — Coefficients of the transfer function for the apparent mass of the seated body without a back support under y-axis vibration

Coefficient	$H(s)$	Coefficient	$H(s)$
K	$8,154 \times 10^{15}$	C_1	$2,675 \times 10^{10}$
A_1	$1,191 \times 10^1$	D_1	$1,745 \times 10^{15}$
B_1	$2,420 \times 10^1$	C_2	$1,025 \times 10^2$
A_2	$1,400 \times 10^1$	D_2	$1,345 \times 10^2$
B_2	$5,490 \times 10^2$	C_3	$1,690 \times 10^1$
A_3	$-2,204$	D_3	$1,319 \times 10^2$
B_3	$1,400 \times 10^4$	C_4	$1,576 \times 10^1$
		D_4	$5,115 \times 10^2$

**Key**

X frequency in Hz

Y1 modulus in kg

Y2 phase in °

NOTE For an explanation of the curves, see [4.1](#).**Figure C.4 — Comparison between the transfer function (dotted line) and the range of idealized values for the apparent mass of the seated body without a back support under y-axis vibration**