International Standard

ISO 10326-3

Mechanical vibration — Laboratory method for evaluating vehicle seat vibration —

Part 3: Specification of dynamic dummies for Z-axis motion

Vibrations mécaniques — Méthode en laboratoire pour l'évaluation des vibrations du siège de véhicule —

Partie 3: Spécifications des mannequins dynamiques pour le mouvement dans l'axe Z

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Foreword

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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 document 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).

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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*.

A list of all parts in the ISO 10326 series can be found on the ISO website.

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

Vehicle seats play an important role in reducing the vibration transmitted to occupants. While conventional seats are widely used in transport vehicles such as cars, buses, trains, and airplanes, suspension seats are commonly adopted to cope with severe vibration environments in earth-moving machinery, agricultural wheeled tractors, and industrial trucks.

It is often required that the dynamic performance of vehicle seats be tested in the laboratory. The International Organization for Standardization and the European Committee for Standardization have published several standards defining laboratory methods for evaluating the dynamic performance of different types of vehicle seats. Such standards include ISO 7096[4] for earth-moving machinery, ISO 5007[1] for agricultural wheeled tractors, and EN 13490[5] for industrial trucks. They require that the seat effective amplitude transmissibility (SEAT) factor, an important dynamic performance index of vehicle seats, be obtained experimentally using both a light and a heavy participant, see Annex D.

As has been recognized in the practical use of the mentioned standards, finding suitable participants for vibration tests of vehicle seats is frequently neither easy nor convenient. The use of participants also raises safety and ethics concerns. These issues have motivated the design and development of dynamic dummies that can replace participants for vibration tests of vehicle seats.

Regardless of its shape and structure, a dynamic dummy that complies with this document is considered to meet the minimum requirements for the purpose. In particular, actual operating conditions may impose more restrictive requirements.

Conformity with this document should not be interpreted as a confirmation that the dynamic dummies passing the validation test necessarily yields seat vibration transmissibility characteristics duplicating those that are obtained when using participants.

Mechanical vibration — Laboratory method for evaluating vehicle seat vibration —

Part 3:
Specification of dynamic dummies for Z-axis motion

1 Scope

This document specifies dynamic dummies used as replacements for participants in vibration tests of vehicle seats in laboratory.

This document is applicable to seats installed in earth-moving machinery, agricultural wheeled tractors, and industrial trucks.

This document specifies technical requirements, acceptance criteria, and a validation test for dynamic dummies representing the human body in two mass groups: lightweight (52 kg to 55 kg) and heavyweight (98 kg to 115 kg). It only applies to passive and active dynamic dummies used for vibration tests of vehicle seats in the Z-axis (vertical) direction.

This document defines, for the two mass groups, the biodynamic response characteristics that the dynamic dummies are required to reproduce to represent those of the participants to be replaced. This document gives guidance on conducting future research to explore the degree of convergence that can be reached when the dynamic performance of seats is measured with participants and with dynamic dummies conforming to this document.

NOTE 1 For seat testing, results have shown that the benefit of using a dynamic dummy is highly dependent on the excitation and dynamic characteristics of the seats. Depending on the type of vibration excitation applied, studies have suggested that the use of dynamic dummies can show benefit over an inert mass of equivalent weight only when testing suspension seats with higher natural frequency (>2 Hz).

NOTE 2 The use of dynamic dummies has been reported to tend to overestimate the vibration isolation performance of seats compared with that measured with participants. Several factors can be in cause and require further investigation, one of them being the influence of the legs possibly not being adequately considered when using dynamic dummies.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitute 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 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

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

ISO 8041-1, *Human response to vibration — Measuring instrumentation — Part 1: General purpose vibration meters*

ISO 10326-1:2016, *Mechanical vibration — Laboratory method for evaluating vehicle seat vibration — Part 1: Basic requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041, ISO 5805, and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://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

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

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: For the purposes of this document, force and acceleration are measured at the same point, this being the point of introduction of vibration. Accordingly, only direct apparent mass (also known as driving point apparent mass) is considered in this document.

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

[SOURCE: ISO 5982:2019, 3.1, modified — Note 2 to entry has been adapted.]

3.2
dynamic dummy
test device or mechanically realizable human analogue model that simulates one or more of the dynamic characteristics of the human body

[SOURCE: ISO 5805:1997, 5.5, modified — Note to entry has been deleted.]

3.3
passive dynamic dummy
dynamic dummy (3.2) that cannot adaptively change its parameters.

Note 1 to entry: A passive dynamic dummy can reproduce the apparent mass of a small number of notional human bodies.

Note 2 to entry: A passive dynamic dummy can be constructed with passive (namely, unpowered) mechanical components such as masses, springs, and dampers.

Note 3 to entry: An example of passive dynamic dummy is shown in Figure 1. See Annex B for more information.

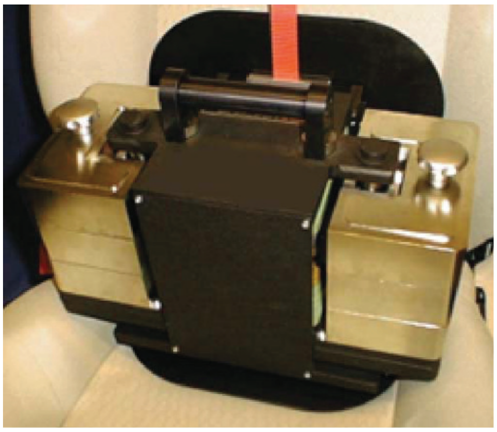


Figure 1 — Example of passive dynamic dummy

3.4
active dynamic dummy
dynamic dummy (3.2) that can adaptively change its parameters

Note 1 to entry: An active dynamic dummy can reproduce the apparent mass of a larger number of notional human bodies than a passive dynamic dummy can.

Note 2 to entry: An active dynamic dummy can be constructed with active (namely, powered) mechanical components such as actuators and control systems.

Note 3 to entry: Examples of active dynamic dummies are shown in Figure 2. See Annex C for more information.

Figure 2 — Examples of active dynamic dummies

4 Symbols and abbreviated terms

$a(t)$	acceleration time history in the Z-axis (vertical) direction, m·s^{-2}
$F(t)$	force time history in the Z-axis (vertical) direction, N
f	frequency, Hz
$M(f)$	apparent mass at the dummy–seat interface in the Z-axis (vertical) direction, kg
$G_{aF}(f)$	cross power spectral density of acceleration and force at the dummy–seat interface, N(m·s^{-2})/Hz
$G_{\mathrm{aa}}(f)$	auto power spectral density of acceleration at the dummy–seat interface, (m·s^{-2})^2/Hz
t	time, s

5 Measuring instrumentation and vibration equipment

Measuring instrumentation shall be in accordance with ISO 8041-1 and ISO 10326-1:2016, Clauses 5. Vibration equipment shall be in accordance with ISO 10326-1:2016, Clause 6.

The minimum signal bandwidth shall be from 0,5 Hz to 20 Hz.

Acceleration shall be measured with an accelerometer attached to the centre of a semi-rigid mounting disc in accordance with ISO 10326-1:2016, 5.2.3.

Force shall be measured with a force transducer.

6 Requirements for dynamic dummies

6.1 Mass

The purpose of a dynamic dummy is to replace as an alternative the participants for vibration tests of vehicle seats when applying ISO 7096[4], ISO 5007[1] and EN 13490[5]. In terms of body mass, two groups of participants are considered in the mentioned standards: lightweight (52 kg to 55 kg), and heavyweight (98 kg to 115 kg).

Considering that the sitting mass of the occupant of a seat (namely, the fraction of the mass of the occupant of a seat supported by the seat itself) is approximately 75 % of the body mass of the occupant, the mass of the dynamic dummy shall be between 39,0 kg and 41,3 kg for the lightweight group, and between 73,5 kg and 86,3 kg for the heavyweight group.

6.2 Mechanical components

Mechanical components such as masses, springs and dampers can be used in the construction of a dynamic dummy to approximate the apparent mass of some notional human bodies. The properties of such mechanical components can be optimised by referring to the pertinent characteristics of the corresponding notional human bodies. Springs shall have low internal friction to approximate the ideal behaviour. Bearings and guides may be used in the dummy structure to provide kinematic pairs between moving and stationary parts. The mechanical properties of these components may change over time which may affect the dynamic performance of the dummy. The dummy shall be checked regularly following the method in Clause 7.

6.3 Seat contact

The dynamic dummy shall have appropriate supporting structures to establish contact with seat cushion and seat back. The bottom supporting structure of the dynamic dummy shall rest on the seat cushion; its shape can be either flat (e.g. similar to the one of the SIP device defined in ISO 5353[2]) or contoured. The back supporting structure of the dynamic dummy shall rest on the seat back to provide stability and to prevent the dynamic dummy from falling during vibration tests. The area of the dummy–seat cushion interface shall be similar to the area of a person–seat cushion interface. Friction at the dummy-seat interface shall be controlled so that no sliding motion occurs.

A seat belt or harness may be used to stabilise the dummy on the seat. The seat belt or harness shall only be used between the frame of the dynamic dummy and the seat, but it shall not constrain the movement of the moving parts of the dynamic dummy and shall not generate additional compressive deformation of either seat cushion or seat back.

To obtain a good fit, the dynamic dummy can be placed on the seat following the procedure recommended in ISO 5353:1995, 5.3.2.

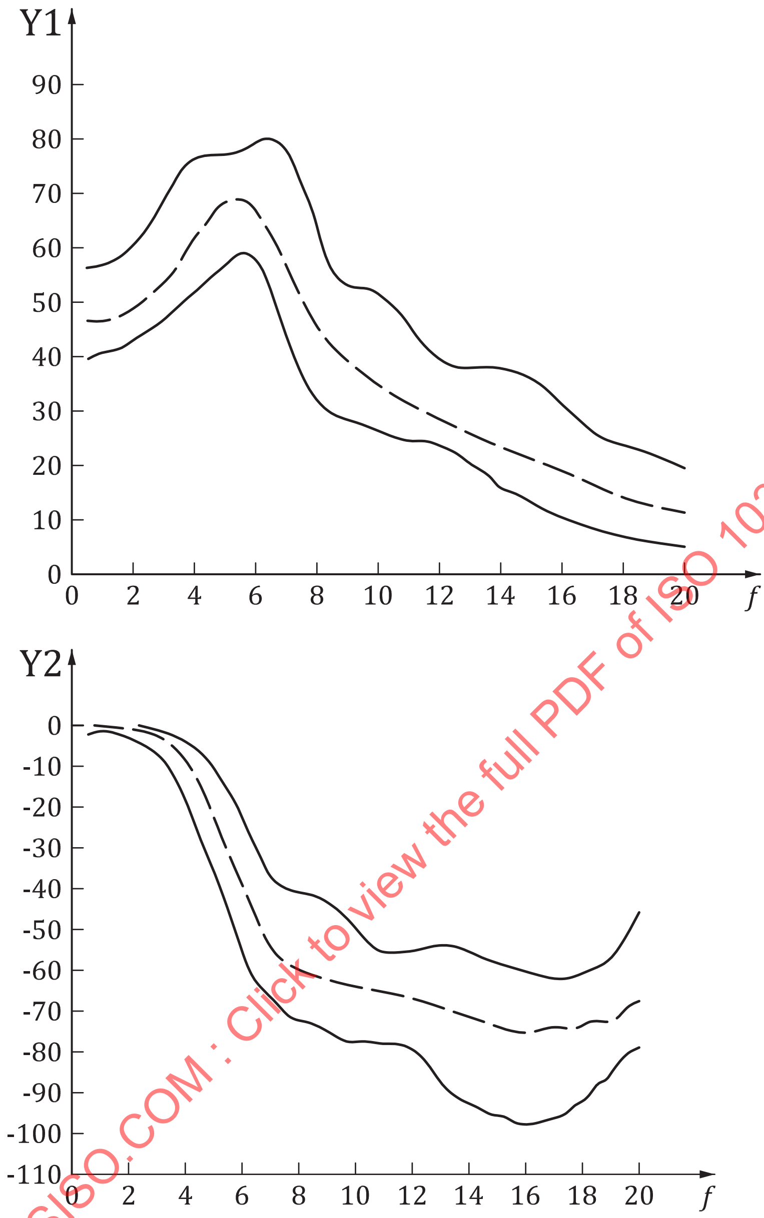
6.4 Apparent mass

The dynamic dummy shall reproduce the idealized Z-axis (vertical) apparent mass at seat cushion of a lightweight participant (52 kg to 55 kg) and/or a heavyweight participant (98 kg to 115 kg) sitting on a rigid seat with flat horizontal seat cushion and flat vertical seat back under Z-axis (vertical) vibration.

Figure 3 shows modulus and phase of the mean (target) and range of idealized Z-axis (vertical) apparent mass at seat cushion of the lightweight (52 kg to 55 kg) group sitting on a rigid seat with flat horizontal seat cushion and flat vertical seat back under Z-axis (vertical) vibration. The corresponding numerical data are listed in Table A.1.

Figure 4 shows modulus and phase of the mean (target) and range of idealized Z-axis (vertical) apparent mass at seat cushion of the heavyweight (98 kg to 115 kg) group sitting on a rigid seat with flat horizontal seat cushion and flat vertical seat back under Z-axis (vertical) vibration. The corresponding numerical data are listed in Table A.2.

The apparent mass reproduced by a dynamic dummy shall lie within the pertinent range of idealized values in the frequency band from 0,5 Hz to 20 Hz as shown in Figures 3 and 4.



Key

Y1 modulus of apparent mass, kg

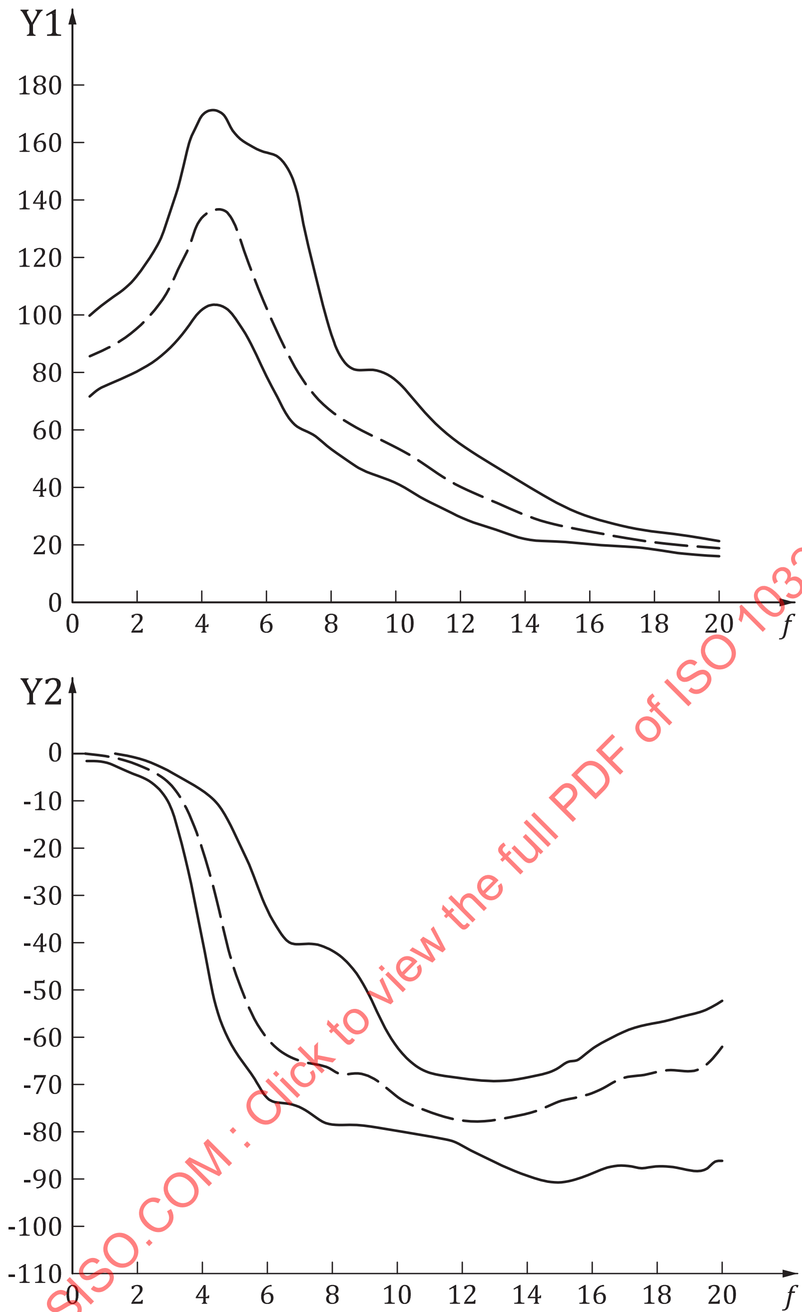
Y2 phase of apparent mass, degree

f frequency, Hz

——— range of idealized values

— — — mean of idealized values

Figure 3 — Modulus and phase of the mean (target) and range of idealized Z-axis (vertical) apparent mass at seat cushion of the lightweight (52 kg to 55 kg) group



Key

Y1 modulus of apparent mass, kg

Y2 phase of apparent mass, degree

f frequency, Hz

——— range of idealized values

— — — mean of idealized values

Figure 4 — Modulus and phase of the mean (target) and range of idealized Z-axis (vertical) apparent mass at seat cushion of the heavyweight (98 kg to 115 kg) group

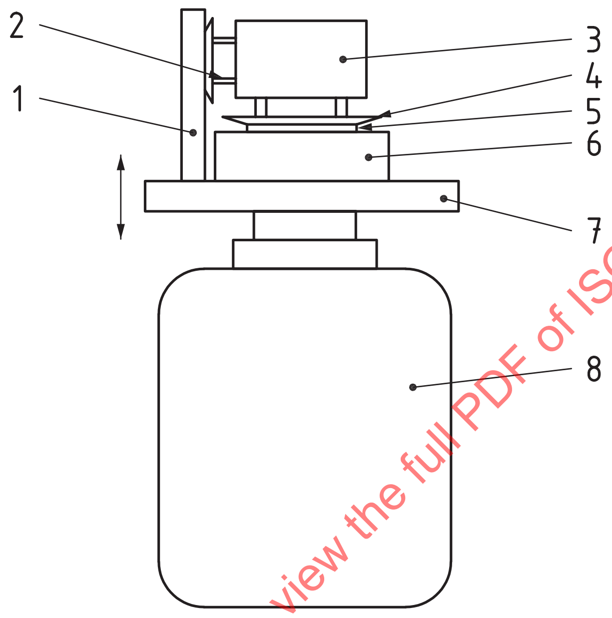
7 Validation test for dynamic dummies

Before a dynamic dummy can be used to replace participants for vibration tests of vehicle seats, it shall pass a validation test in which its apparent mass is evaluated experimentally using a rigid seat with flat horizontal seat cushion and flat vertical seat back.

The validation test shall be conducted by using suitable measuring instrumentation and vibration equipment, by following the recommendations in Clause 5, and by satisfying the basic requirements specified in ISO 10326-1.

An example setup for measuring the apparent mass of a dynamic dummy is shown in Figure 5.

A force transducer shall be attached to the rigid seat cushion or the vibrating table of a vibrator. The dynamic dummy shall be secured to the top surface of the force transducer plate and to the rigid seat back (or a back supporting structure fixed on the vibrator) through the cushion and backrest indenters of the dynamic dummy. An accelerometer shall be attached to the interface between the dynamic dummy and the force transducer plate to measure the input acceleration. A seat belt or harness may be used to prevent the dummy from falling but shall not influence the motion of the moving parts of the dynamic dummy.



Key

1 supporting structure
2 backrest indenter of the dummy
3 dynamic dummy
4 cushion indenter of the dummy
5 accelerometer (SIT-pad)
6 force transducer plate
7 vibrating table
8 vibrator

Figure 5 — Example setup for measuring the apparent mass of a dynamic dummy

During the validation test, the force $F(t)$ and the acceleration $a(t)$ at the interface between the dynamic dummy and the force transducer plate shall be measured in the Z-axis (vertical) direction. Acceleration excitations shall have vertical (Z-axis) direction and stationary random broadband waveform with a root-mean-square value of (1,0 ± 0,05) ms^{-2} in the frequency band from 0,5 Hz to 20 Hz. The duration of an acceleration excitation shall be no less than 60 s.

Before calculating apparent mass, the mass cancellation procedure shall be applied to minimize the influence of the mass of the force transducer. The mass cancellation procedure may be performed in the time domain by multiplying the acceleration time-history measured on the seat surface with the mass of the plate above the force transducer and then subtracted from the measured force.

The Z-axis (vertical) apparent mass at the dummy–seat interface, $M(f)$, shall be obtained in the frequency band from 0,5 Hz to 20 Hz as the ratio of the cross power spectral density of acceleration and force at the dummy–seat interface, $G_{aF}(f)$, to the auto power spectral density of acceleration at the dummy–seat interface, $G_{aa}(f)$, as given by Formula (1):

$$M(f)=\frac{G_{aF}(f)}{G_{aa}(f)} \tag{1}$$

The measurement shall be repeated three times consecutively. Final values of modulus and phase of apparent mass shall be obtained by calculating the arithmetic mean of the experimental data collected during the three repetitions.

For the dynamic dummy to pass the validation test, the final values of modulus and phase of apparent mass shall be within the range of idealized values over the frequency band from 0,5 Hz to 20 Hz as specified in 6.4.

To assure that the dynamic performance of the dummy remains to be valid during later measurements, the apparent mass of the dummy shall be checked regularly or once every 6 months following the method described in Clause 7.

8 Test report

The test report of the validation test shall present text, photographs, and plots of force, acceleration, and apparent mass data.

The test report shall include at least the following data:

a) manufacturer, model, and description of the dynamic dummy;

b) a reference to this document, i.e. ISO 10326-3:2024;

c) test date and test laboratory information;

d) method of securing the dynamic dummy to the rigid seat or vibrator;

e) mass of the dynamic dummy;

f) description and calibration information of the equipment;

g) description and photograph(s) of the dummy–seat assembly and of the experimental setup;

h) description of mass cancellation, measurement duration, and vibration excitation level for each run;

i) description of test run-in, execution sequence, and data processing;

j) example graphs showing force and acceleration time histories as described in Clause 7;

k) graphs showing final values of modulus and phase of apparent mass superimposed on the range of idealized values for the appropriate (lightweight or heavyweight) group;

l) ranges of ambient temperature and relative humidity during the tests;

m) any deviations from the procedure;

n) any unusual features observed.

The report shall provide a clear statement certifying whether or not the dynamic dummy passed the validation test in accordance with this document.

Annex A
(informative)

Idealized Z-axis (vertical) apparent mass at seat cushion of a lightweight (52 kg to 55 kg) group and of a heavyweight (98 kg to 115 kg) group

The apparent mass values listed in this annex are based on published studies[6][7][8][9][10][11] investigating the biodynamic response of the seated human body exposed to Z-axis (vertical) vibration with vertical backrest contact. The data for lightweight (52 kg to 55 kg) group were obtained from 15 male and female participants having body mass between 53,6 kg and 58,7 kg (mean value 56,3 kg and standard deviation 1,5 kg). The data for the heavyweight (98 kg to 115 kg) group were obtained from 15 male participants having body mass between 96 kg and 117 kg (mean value 104,4 kg and standard deviation 6,3 kg). Tables A.1 and A.2 list modulus and phase of the mean (target) and range of idealized Z-axis (vertical) apparent mass at seat cushion of the lightweight (52 kg to 55 kg) group and heavyweight (98 kg to 115 kg) group sitting on a rigid seat with flat horizontal seat cushion and flat vertical seat back under Z-axis (vertical) vibration

Table A.1 — Modulus and phase of the mean (target) and range of idealized Z-axis (vertical) apparent mass at seat cushion of the lightweight (52 kg to 55 kg) group

Frequency Hz	Modulus kg			Phase degree		
	Mean	Upper limit	Lower limit	Mean	Upper limit	Lower limit
0,5	46,4	56,3	39,5	0,7	9,4	-2,4
0,75	46,5	56,6	40,1	-0,1	3,8	-1,7
1	46,7	57,0	40,5	-0,2	2,4	-1,7
1,25	47,0	57,5	40,9	-0,3	0,6	-1,7
1,5	47,6	58,3	41,5	-0,9	0,3	-2,0
1,75	48,2	59,3	42,2	-0,9	0,2	-2,5
2	49,0	60,7	43,0	-1,0	0,2	-3,2
2,25	50,0	62,3	43,9	-1,3	0,1	-4,0
2,5	51,2	64,2	44,8	-1,6	-0,2	-5,0
2,75	52,4	66,6	45,8	-2,4	-0,6	-6,1
3	53,8	69,0	46,9	-3,0	-1,3	-7,4
3,25	55,4	71,5	48,0	-3,9	-2,0	-9,4
3,5	57,3	73,9	49,4	-5,2	-2,7	-12,0
3,75	59,6	75,7	50,7	-7,2	-3,5	-15,4
4	62,2	76,7	52,1	-9,2	-4,5	-19,3
4,25	63,8	77,1	53,4	-11,8	-5,7	-23,9
4,5	66,0	77,2	54,7	-15,1	-7,2	-28,3
4,75	67,9	77,3	55,9	-19,5	-9,0	-32,1
5	68,6	77,6	57,3	-23,3	-11,3	-36,4
5,25	69,0	77,8	58,3	-26,9	-13,8	-41,3
5,5	68,7	78,2	59,1	-32,2	-16,5	-45,8
5,75	67,6	79,0	59,0	-35,4	-19,8	-50,6
6	65,8	79,8	57,7	-39,7	-23,7	-55,8

Table A.1 *(continued)*

Frequency Hz	Modulus kg			Phase degree		
	Mean	Upper limit	Lower limit	Mean	Upper limit	Lower limit
6,25	64,0	80,3	55,3	-43,8	-27,3	-59,6
6,5	62,3	79,7	51,9	-47,3	-31,2	-62,6
6,75	60,1	79,5	47,7	-49,4	-34,6	-65,4
7	55,3	78,1	43,5	-53,5	-37,2	-66,9
7,25	53,4	75,3	39,6	-56,3	-39,0	-68,5
7,5	50,6	71,6	36,3	-57,4	-40,0	-70,1
7,75	47,6	68,1	33,7	-58,3	-40,5	-71,5
8	45,3	63,3	31,7	-59,6	-40,9	-72,2
8,25	43,7	59,1	30,4	-60,6	-41,3	-72,7
8,5	41,5	55,9	29,5	-60,9	-41,6	-73,0
8,75	40,0	53,9	28,9	-60,4	-42,2	-74,0
9	39,2	53,0	28,3	-60,8	-43,1	-74,8
9,25	38,3	52,8	27,9	-61,7	-44,2	-75,7
9,5	36,9	52,7	27,4	-62,1	-45,6	-76,9
9,75	35,8	52,4	26,8	-63,0	-47,4	-77,7
10	34,9	51,8	26,1	-63,4	-49,6	-77,7
10,25	34,0	50,8	25,5	-64,0	-51,6	-77,6
10,5	32,8	49,4	24,9	-64,5	-53,2	-77,7
10,75	31,8	47,7	24,3	-65,1	-54,6	-77,9
11	30,9	45,9	24,1	-65,4	-55,5	-78,1
11,25	30,5	44,0	24,1	-66,2	-55,7	-78,1
11,5	29,7	42,4	24,1	-66,1	-55,7	-78,1
11,75	29,0	40,8	23,9	-66,5	-55,6	-78,5
12	28,3	39,7	23,5	-67,1	-55,3	-79,4
12,25	27,3	38,8	22,9	-67,5	-55,0	-80,9
12,5	26,8	38,3	22,0	-68,3	-54,5	-82,7
12,75	26,4	37,9	21,1	-69,2	-54,1	-85,0
13	25,7	37,9	20,1	-69,1	-53,9	-87,1
13,25	25,1	38,0	19,1	-69,9	-53,9	-89,1
13,5	24,4	380	18,0	-70,6	-54,0	-90,4
13,75	23,8	37,9	17,1	-71,0	-54,7	-91,6
14	23,1	37,6	16,2	-71,6	-55,6	-92,7
14,25	22,6	37,3	15,3	-72,4	-56,3	-93,4
14,5	21,8	36,9	14,6	-72,7	-57,0	-94,0
14,75	21,2	36,3	13,9	-73,2	-57,6	-95,1
15	20,7	35,6	13,2	-73,9	-58,1	-95,8
15,25	20,3	34,8	12,5	-74,5	-58,6	-95,9
15,5	19,6	33,8	11,8	-74,7	-59,2	-96,7
15,75	19,0	32,5	11,2	-74,2	-59,8	-97,1
16	18,5	31,1	10,5	-74,9	-60,2	-97,3
16,25	17,6	29,8	9,9	-75,3	-60,7	-97,3

Table A.1 *(continued)*

Frequency Hz	Modulus kg			Phase degree		
	Mean	Upper limit	Lower limit	Mean	Upper limit	Lower limit
16,5	17,4	28,4	9,4	-74,0	-61,0	-97,3
16,75	16,7	27,0	8,9	-73,7	-61,3	-96,7
17	15,9	26,0	8,5	-73,9	-61,4	-96,0
17,25	15,5	25,1	8,0	-73,7	-61,7	-95,5
17,5	15,1	24,4	7,7	-73,4	-61,5	-94,3
17,75	14,9	23,9	7,3	-73,8	-61,1	-93,2
18	14,3	23,5	7,0	-73,6	-60,5	-92,2
18,25	13,9	23,0	6,6	-72,6	-59,9	-90,2
18,5	13,6	22,5	6,3	-72,0	-59,2	-87,8
18,75	13,2	22,1	6,0	-71,8	-57,9	-87,3
19	12,8	21,5	5,7	-72,3	-56,4	-85,6
19,25	12,6	21,1	5,5	-72,3	-54,5	-83,1
19,5	12,4	20,9	5,3	-69,5	-52,0	-82,0
19,75	11,9	19,9	5,1	-67,5	-48,9	-79,5
20	11,5	19,1	5,0	-67,6	-45,8	-79,2

Table A.2 — Modulus and phase of the mean (target) and range of idealized Z-axis (vertical) apparent mass at seat cushion of the heavyweight (98 kg to 115 kg) group

Frequency Hz	Modulus kg			Phase degree		
	Mean	Upper limit	Lower limit	Mean	Upper limit	Lower limit
0,5	85,7	99,8	71,6	-0,2	1,3	-1,7
0,75	86,6	102,1	73,9	-0,5	0,8	-1,7
1	87,9	104,1	75,2	-0,5	0,5	-1,9
1,25	89,6	106,3	76,7	-0,9	0,1	-2,4
1,5	91,2	108,8	77,8	-1,1	-0,1	-3,2
1,75	93,1	111,5	79,1	-1,5	-0,5	-3,8
2	95,4	114,7	80,5	-2,2	-1,0	-4,4
2,25	98,1	118,3	82,1	-2,8	-1,5	-5,3
2,5	101,6	122,4	83,8	-3,4	-2,1	-6,4
2,75	105,0	128,1	85,9	-4,8	-2,9	-8,0
3	109,6	135,3	88,6	-6,4	-3,8	-10,5
3,25	115,6	144,5	91,8	-8,5	-4,8	-15,1
3,5	121,2	155,4	95,5	-11,4	-5,7	-22,0
3,75	127,3	164,7	99,0	-15,3	-6,6	-29,9
4	133,9	170,0	101,9	-20,0	-7,5	-38,4
4,25	135,6	171,7	103,6	-25,0	-9,0	-47,5
4,5	137,7	171,1	103,7	-31,4	-10,7	-54,5
4,75	136,4	168,4	102,2	-38,9	-13,1	-58,6
5	131,5	164,3	99,7	-44,3	-16,3	-62,2
5,25	125,8	160,7	95,8	-49,0	-20,0	-65,6

Table A.2 *(continued)*

Frequency Hz	Modulus kg			Phase degree		
	Mean	Upper limit	Lower limit	Mean	Upper limit	Lower limit
5,5	117,4	159,3	91,0	-54,7	-23,8	-68,0
5,75	110,1	157,9	85,2	-57,4	-28,6	-70,1
6	102,7	157,2	78,9	-60,2	-33,0	-72,7
6,25	95,7	156,4	72,7	-62,3	-36,1	-73,8
6,5	90,1	154,0	67,5	-63,4	-38,5	-73,8
6,75	86,0	149,1	63,3	-63,4	-40,1	-74,1
7	79,8	141,0	60,5	-63,9	-40,3	-74,7
7,25	76,5	129,2	59,3	-65,4	-40,0	-75,4
7,5	73,4	116,9	58,2	-65,2	-40,2	-76,5
7,75	70,2	105,9	56,3	-66,1	-40,7	-77,7
8	67,4	95,4	54,3	-67,0	-41,5	-77,9
8,25	64,8	88,0	52,5	-67,8	-42,6	-78,0
8,5	62,7	83,5	49,7	-67,7	-44,1	-78,3
8,75	61,4	81,3	47,3	-67,7	-46,1	-78,3
9	59,8	80,8	45,8	-68,3	-48,7	-78,3
9,25	57,6	81,1	44,8	-68,6	-51,7	-78,9
9,5	56,4	80,5	43,4	-69,4	-55,3	-79,5
9,75	55,4	79,4	42,5	-71,2	-58,8	-79,5
10	54,2	77,7	41,6	-72,0	-61,9	-79,7
10,25	52,9	75,1	40,3	-73,0	-64,1	-80,0
10,5	51,0	71,9	38,7	-73,9	-65,7	-80,3
10,75	48,7	69,0	37,1	-75,1	-66,8	-80,4
11	47,1	65,8	35,5	-76,0	-67,3	-80,8
11,25	45,4	62,9	33,9	-76,6	-67,7	-81,1
11,5	43,5	60,3	32,4	-77,0	-67,9	-81,4
11,75	42,0	57,6	31,0	-77,2	-68,1	-82,0
12	40,5	55,2	29, 8	-77,0	-68,1	-82,9
12,25	38,4	53,3	28,6	-77,5	-68,3	-83,8
12,5	37,3	51,2	27,6	-77,5	-68,6	-84,4
12,75	36,4	49,4	26,6	-77,8	-68,8	-85,3
13	35,0	47,9	25,7	-76,7	-69,1	-86,2
13,25	33,8	46,4	24,8	-76,6	-69,1	-86,9
13,5	32,4	44,5	23,9	-76,7	-69,1	-87,6
13,75	31,6	42,9	23,2	-76,3	-69,0	-88,5
14	30,3	41,3	22,6	-75,7	-68,8	-89,2
14,25	29,4	39,7	22,1	-75,4	-68,1	-89,5
14,5	28,6	37,8	21,8	-74,3	-67,6	-90,0
14,75	27,6	36,3	21,6	-73,9	-66,9	-90,4
15	27,0	34,8	21,4	-73,7	-66,0	-90,5
15,25	26,5	33,3	21,2	-73,5	-65,2	-90,3
15,5	25,8	32,0	20,9	-73,0	-64,6	-89,7

Table A.2 *(continued)*

Frequency Hz	**Modulus** kg			**Phase** degree		
	Mean	Upper limit	Lower limit	Mean	Upper limit	Lower limit
15,75	25,2	30,8	20,5	-71,6	-63,4	-89,3
16	24,7	29,8	20,3	-71,5	-62,5	-88,5
16,25	23,8	28,8	20,1	-70,8	-61,3	-87,7
16,5	24,0	28,0	19,9	-69,7	-60,2	-87,3
16,75	23,5	27,3	19,8	-69,0	-59,3	-87,4
17	22,7	26,7	19,8	-68,4	-58,7	-87,1
17,25	22,4	25,9	19,5	-68,1	-58,0	-87,2
17,5	21,9	25,4	19,1	-67,7	-57,7	-87,4
17,75	21,5	25,0	18,7	-67,9	-57,2	-87,3
18	21,0	24,6	18,4	-67,5	-56,6	-87,1
18,25	20,8	24,3	18,0	-66,8	-56,3	-87,1
18,5	20,6	23,9	17,5	-66,5	-56,0	-87,4
18,75	20,	23,5	17,1	-66,4	-55,5	-87,8
19	19,5	23,1	16,8	-66,9	-55,1	-87,9
19,25	19,3	22,8	16,5	-66,7	-54,5	-87,7
19,5	19,3	22,4	16,3	-64,8	-53,8	-87,5
19,75	19,0	22,3	16,2	-63,4	-52,7	-86,1
20	18,6	21,6	15,8	-63,7	-52,2	-86,0

Annex B
(informative)

An example of passive dynamic dummy

This annex provides an example of passive dynamic dummy used for seat tests.

This passive dynamic dummy replicates the mean Z-axis (vertical) apparent mass of sixty participants exposed to acceleration excitation having vertical (Z-axis) direction and stationary random broadband waveform with a root-mean-square value of 1,0 ms^{-2} in the frequency band from 0,5 Hz to 30 Hz. The passive dynamic dummy has a mass of 53,4 kg (corresponding to a body mass of approximately 72 kg) and consists of a one-degree-of-freedom passive simulator unit with articulated seat cushion and seat back indenters. Figure B.1 shows the passive dynamic dummy represented as a one-degree-of-freedom discrete-element model.

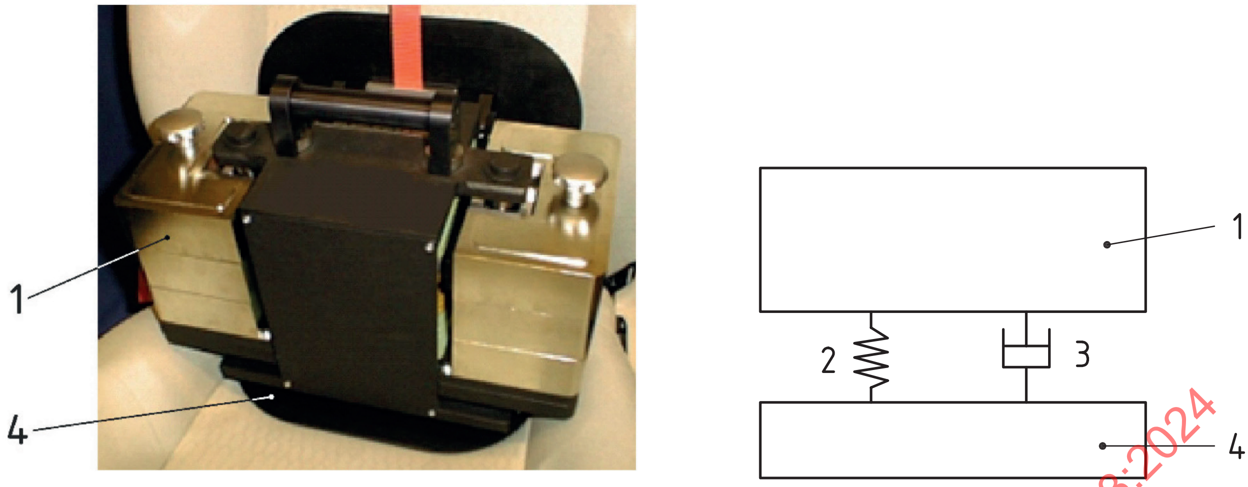
The passive simulator unit consists of a moving mass constrained to move vertically on two chrome-plated precision shafts. A dashpot provides damping to the unit. The internal friction of the unit is low to ensure a linear response over a range of input magnitudes suitable for seat testing.

The passive dynamic dummy interfaces with the seat surface using two shaped indenters (SIT-bars) at seat cushion and seat back. Figure B.2 shows the design of a SIT-bar indenter[12]. The seat cushion indenter is articulated to the bottom of the frame to allow adjustment of the position of the passive dynamic dummy on the seat. The seat back indenter is decoupled from the main unit using linear bearings and can be attached to the seat back using a ratchet strap. This configuration minimises the influence of the seat back upon the response at the seat cushion and improves the stability of the passive dynamic dummy.

As shown in Figure B.3, the apparent mass of the passive dynamic dummy is in good agreement with the apparent mass of the one-degree-of-freedom discrete-element model shown in Figure B.1.

The mass of this passive dynamic dummy is outside the range specified for the lightweight (52 kg to 55 kg) group and for the heavyweight (98 kg to 115 kg) group in 6.1.

When exercising with the moving mass 39 kg, the frame mass 5 kg, stiffness 69 070 Nm^{-1}, and damping 1 390 Nsm^{-1}, the apparent mass predicted with the one-degree-of-freedom discrete-element model in Figure B.1 is within the idealised range for the lightweight (52 kg to 55 kg) group, as shown in Figure B.4 (left column). With adjusted parameters (moving mass 71 kg, the frame mass 9 kg, stiffness 76 750 Nm^{-1}, and damping 2 320 Nsm^{-1}), the apparent mass of the one-degree-of-freedom discrete-element model is within the idealised range for the heavyweight (98 kg to 115 kg) group (right column of Figure B.4).



a) Example of passive dynamic dummy used for sea tests **b) One-degree-of-freedom discrete-element model**

Key

1 moving mass 45,6 kg

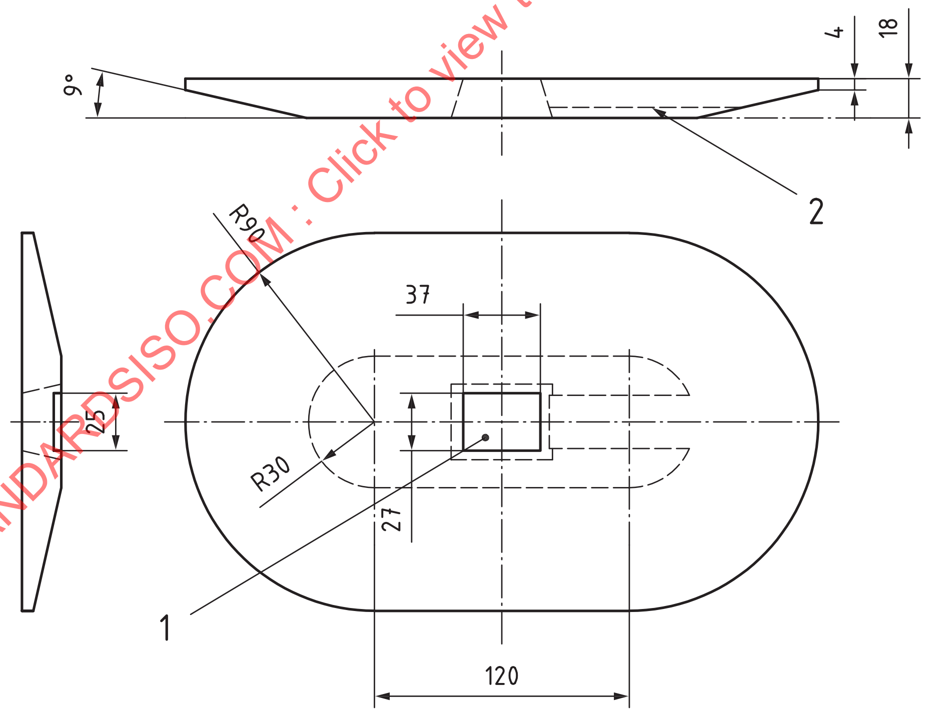
2 spring, stiffness 45 000 Nm^{-1}

3 damper, damping 1 360 Nsm^{-1}

4 frame (including interface indenters), mass 6,0 kg

Figure B.1 — Examples of passive dynamic dummy used for sea tests (left) and the corresponding one-degree-of-freedom discrete-element model (right)

Dimensions in millimetres

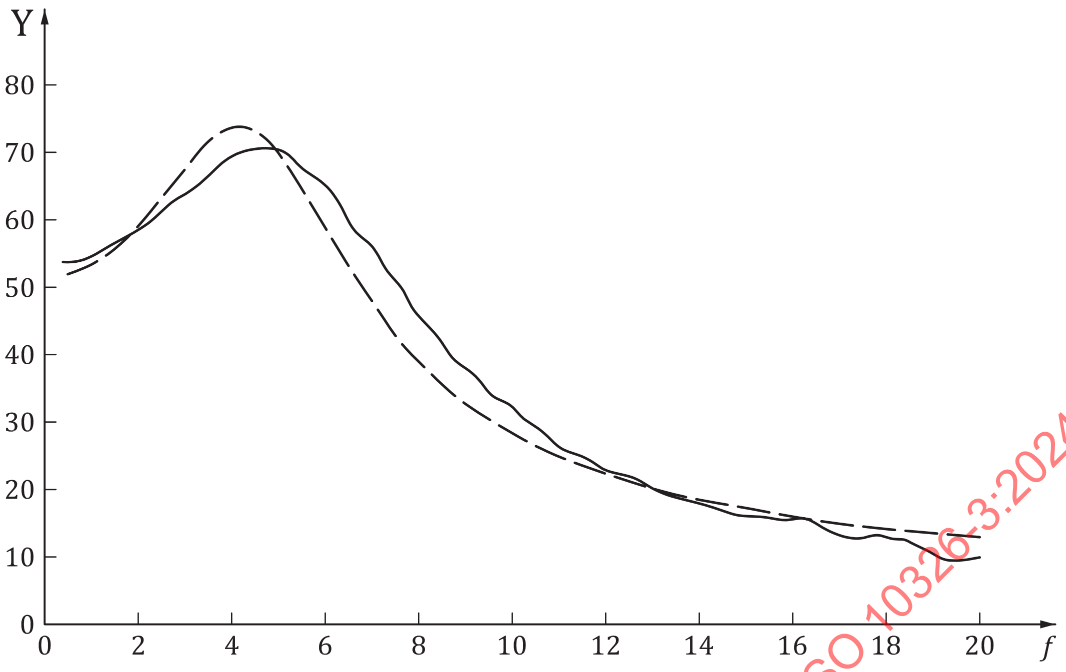


Key

1 hole for mounting three translational accelerometers

2 channel for accelerometer heads

Figure B.2 — Design of a SIT-bar indenter



Key

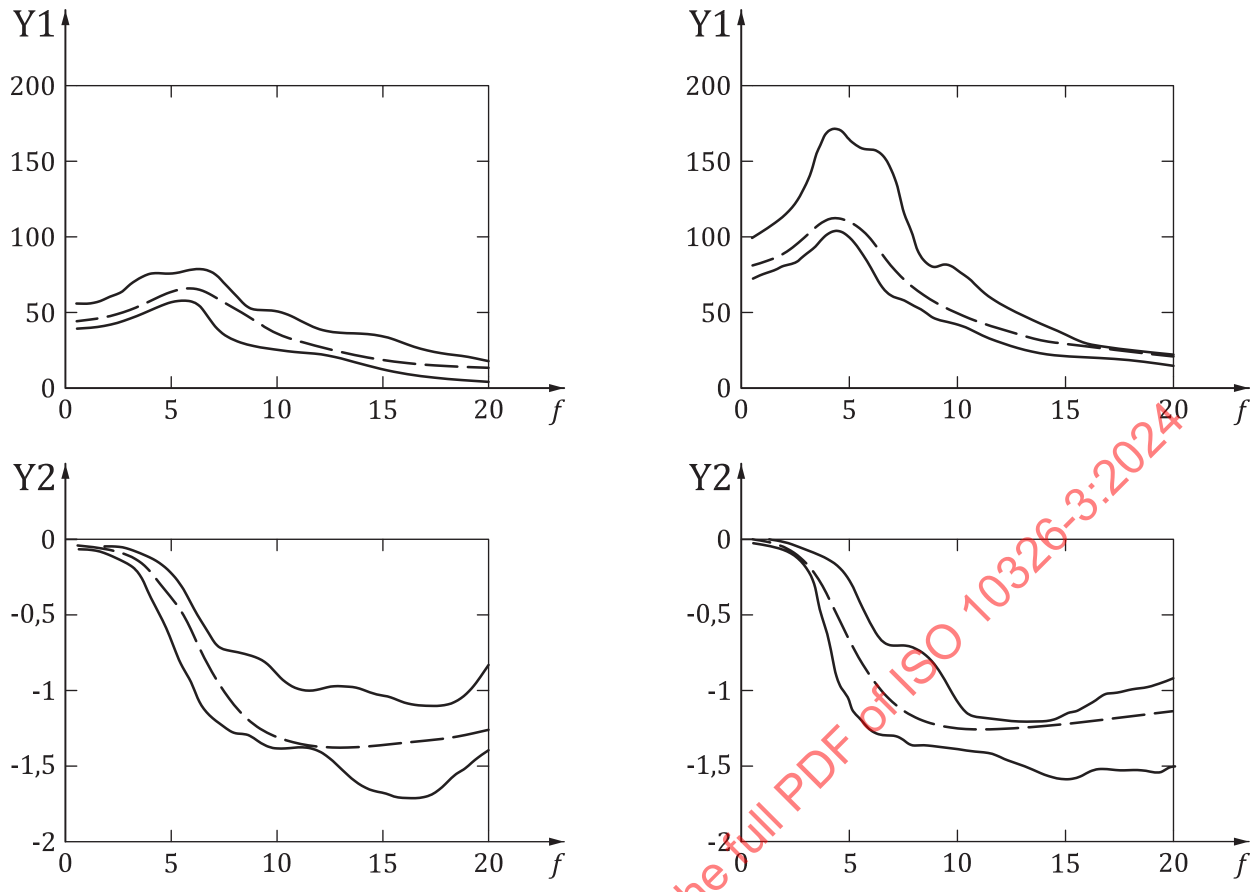
Y modulus of apparent mass, kg

f frequency, Hz

——— passive dynamic dummy

— — — one-degree-of-freedom discrete-element model

Figure B.3 — Apparent mass of the passive dynamic dummy and apparent mass of the corresponding one-degree-of-freedom discrete-element model



a) Lightweight (52 kg to 55 kg) group

b) Heavyweight (98 kg to 115 kg) group

Key

Y1 modulus of apparent mass, kg

Y2 phase of apparent mass, rad

f frequency, Hz

——— range of idealized apparent mass

— — — one-degree-of-freedom discrete-element model

Figure B.4 — Apparent mass of the one-degree-of-freedom discrete-element model with parameters adjusted for the lightweight (52 kg to 55 kg) group and heavyweight (98 kg to 115 kg) groups

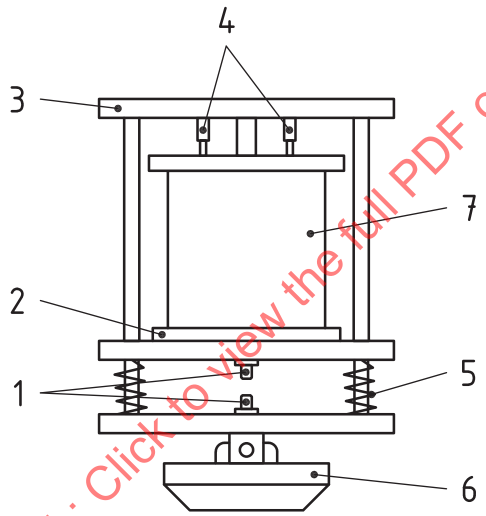
More examples of passive dynamic dummy are available in References [13] and [14] in which the structure of different passive dynamic dummies and their application for laboratory testing of seats were demonstrated.

Annex C
(informative)

Example of active dynamic dummy

This annex provides information on an example of active dynamic dummy used for seat tests[15].

The active dynamic dummy, shown in Figure C.1, has a single moving mass that linear ball bushings running on steel shafts constrain to move in the Z-axis (vertical) direction with respect to a rigid frame. Most of the moving mass is provided by the permanent magnet of an electrodynamic actuator. The moving part of the actuator is fixed to the top of the frame of the active dynamic dummy. The armature of the actuator is immobile with respect to the frame. A linear variable differential transformer (LVDT) displacement transducer and a linear velocity transducer (LVT) are fixed between the frame and the moving mass to provide motion feedback signals driving the actuator. Accelerometers are fixed to the moving mass and to the frame.



Key

1 accelerometers
2 moving mass
3 dummy frame
4 displacement and velocity output
5 spring
6 supporting structure
7 actuator

Figure C.1 — Example of -active dynamic dummy used for seat tests