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МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ

Mechanical vibration and shock — Mechanical transmissibility of the human body in the z direction

Vibrations et chocs mécaniques — Transmissibilité mécanique du corps humain suivant la direction z

Reference number
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Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for approval before their acceptance as International Standards by the ISO Council. They are approved in accordance with ISO procedures requiring at least 75 % approval by the member bodies voting.

International Standard ISO 7962 was prepared by Technical Committee ISO/TC 108, *Mechanical vibration and shock.*

Users should note that all International Standards undergo revision from time to time and that any reference made herein to any other International Standard implies its latest edition, unless otherwise stated.

Mechanical vibration and shock — Mechanical transmissibility of the human body in the z direction

0 Introduction

When considering the effects of shock and vibration on people the dynamic properties of the human body have to be known. One of the possible measurement techniques to assess these properties is mechanical transmissibility. The intention of this International Standard is to draw together available information on transmissibility through the human body, when it is subjected to vibration in the z direction.

1 Scope and field of application

Transmissibility through the human body is a function of three main factors:

a) the posture of the subject;

b) the direction and type of input vibration;

c) the physical characteristics of the subject.

Measurement is possible at many points, with the main areas of concern being the head, neck or shoulder and the hip. In view of the current state of knowledge in this area, standardization in this International Standard is restricted to z-axis vibration for the standing and sitting postures. Currently there is only sufficient information on the transmissibility to the head in the frequency range from 0,5 to 31,5 Hz for whole-body vibration entering the torso in the anatomical z direction through the seat (sitting) or feet (standing).

It is expected that this information on transmissibility will be used in conjunction with other data concerning the effect of vibration and impact in ergonomic design studies. Such work could include computer and analytical design of man-machine systems. It can be of use in perfecting and improving the vibration characteristics of vehicle suspension systems and seats.

2 References

ISO 2041, *Vibration and shock — Vocabulary.*

ISO 2631-1, *Evaluation of human exposure to whole-body vibration — Part 1 : General requirements.*

ISO 5805, *Mechanical vibration and shock affecting man — Vocabulary.*

3 Definitions

For the purpose of this International Standard, the following definitions apply.

3.1 mechanical transmissibility: The complex non-dimensional ratio of the response amplitude of a system in steady-state forced vibration to the excitation amplitude at a given frequency. The ratio may be one of forces, displacements, velocities or accelerations.

NOTE — In the case of non-sinusoidal vibration, transmissibility may be computed from the motion spectra.

3.2 human transmissibility: A quantity, properly expressed as the transmissibility modulus, T, (see 3.3) describing the transfer of whole-body vibration from a point of input into the human body to defined coordinates within a designated anatomical segment.

3.3 transmissibility modulus, T: The ratio of the moduli of the motions.

3.4 phase of transmissibility, φ: The phase difference between output and input motions.

4 Human transmissibility

4.1 General

It should be noted that vibration transmissibility is a function of

a) the human body orientation, posture, and muscle tension with respect to the vibration input;

b) the mechanical coupling between the vibration input and the human body;

c) whether or not a restraint system is used, and if so the characteristics of the restraint system;

d) the human transmissibility which may affect the transmissibility amplitude but which is nearly independent of the frequency due to the response phenomenon.

Results may differ substantially from the average values shown in figure 1, which shows only typical curves. Therefore this International Standard should be used with caution.

The mechanical transmissibility of the human body can only be described provided that the reservation outlined above is borne in mind.

4.2 Frequency range

Transmissibility curves for the human body are only given for the frequency range from 0,5 to 31,5 Hz; although some data exist beyond 31,5 Hz, it is considered that in view of the very low levels of motion the reliability of these data cannot be fully substantiated.

4.3 Linearity

The human body vibrating in the z-axis direction (see ISO 5805) displays a non-linear characteristic. However, to a first approximation, this non-linearity may be disregarded under conditions of normal gravity and acceleration amplitudes not exceeding those used in the determination of the transmissibility values as stated in the annex.

4.4 Posture

Transmissibility depends upon body posture and muscle tension, which in turn are affected by the specific activity of the human being. The basic postures are sitting, standing erect and lying. For excitation in the z-axis direction in the sitting position transmissibility is very similar for the two common conditions, namely excitation of the torso alone and simultaneous excitation of both the torso and the feet.

4.5 Point of measurement

This International Standard only relates to head motion. Even if there is only a vertical input the movement of the head may have both vertical (z axis) and horizontal components. In this International Standard the output shall be taken to be the vertical component of head motion only; this may be subsequently amended when other reliable data become available.

4.6 Body restraints

External mechanical constraints, such as design of the seat itself and seat-back, arm- or foot-rests, seat-belts or harnesses, will also affect vibration transmissibility through the body.

4.7 Limitations of the data available

(See also the annex.)

The data available are such that no conclusions can be drawn with regard to changes in transmissibility according to body weight or stature. In all cases the values have been obtained from sinusoidal vibration of the body. As non-linearities may occur, the curves from sinusoidal vibration should not be taken to apply necessarily to other forms of motion. In general, human responses are similar to those of a simple resonant system, with mass-like behaviour at low frequencies, a resonance range in which the vibration response is greater than is the case with a rigid mass under similar conditions, and with spring-like behaviour at higher frequencies.

5 Presentation of typical transmissibility curves for the human body

Transmissibility of vibration to the head of the human body standing erect or sitting upright has the following general characteristics (illustrated in figure 1):

a) below 2 Hz, the body vibrates like a pure mass and the transmissibility has a value of unity;

b) above that frequency, the transmissibility rises to a maximum in the region of 5 Hz, which is associated with the principal resonance of the human body in response to z-axis excitation; at this point, for a constant input force vibration, the response of the body at the head is approximately 1,5 times as great as would be that of a rigid (i.e. non-resilient) mass under similar conditions of testing;

c) in the range from 5 to 8 Hz, transmissibility decreases;

d) between 8 and 15 Hz, a second resonant response is exhibited;

e) at higher frequencies above 15 Hz, head motion is attenuated and transmissibility assumes values less than 1; it declines steeply above 20 Hz.

The values are derived from those which have been determined from available literature (see Bibliography).

The curves shown in figure 1 show the transmissibility modulus, T, and the phase of transmissibility, φ, of the human body in representative body positions for the frequency range between 0,5 and 31,5 Hz. The modulus is given in terms of a dimensionless ratio of output to input acceleration. The values presented are typical although based on a limited number of subjects.

Figure 2 gives the details of a model with similar overall response. Transmissibility is determined as the output on top of mass, m_1, related to the base input. There is no established correlation between the elements of the model and anatomical segments. Its primary function is to make mathematical computation of z-axis head motion more straightforward. For many comparative purposes in biodynamical analysis and modelling, the mass, m_1, in such a model may, as a practical matter, be identified with the head.

Annex

Human seat-to-head vibration transmissibility in the z axis (standing or sitting)

(This annex forms an integral part of the standard.)

Figure 1 gives a typical curve of experimentally obtained values, together with the characteristics of a simple analogue with a similar response. The figure is derived from information on approximately 50 subjects with a mean body weight of 75 kg and sinusoidal input acceleration amplitudes in the range 2 to 4 $m \cdot s^{-2}$. (In some cases, however, the input acceleration was not given by the author.) Subject posture was in some cases loosely defined. In general, the values relate to an upright sitting or standing posture. In the sitting position, the feet were, in some cases, supported by a foot-rest moving in phase with the seat, and, in other cases, hanging freely from the supporting surface. In the standing position, the knees were in a locked position (standing erect). The surface of the supporting structure (seat, platform) was rigid and flat. No external restraints or inclined back-rests were used.

The experimental data indicated that the transmissibility curves for sitting and standing positions (standing erect) were essentially the same. For this reason, only one curve is presented for both postures.

NOTE — Substantial variation with body mass, size, age and build is to be expected in such biodynamical parameters as principal resonance frequencies and damping factors (which in turn determine the value of transmissibility to the head at resonance) between both individuals and population groups.

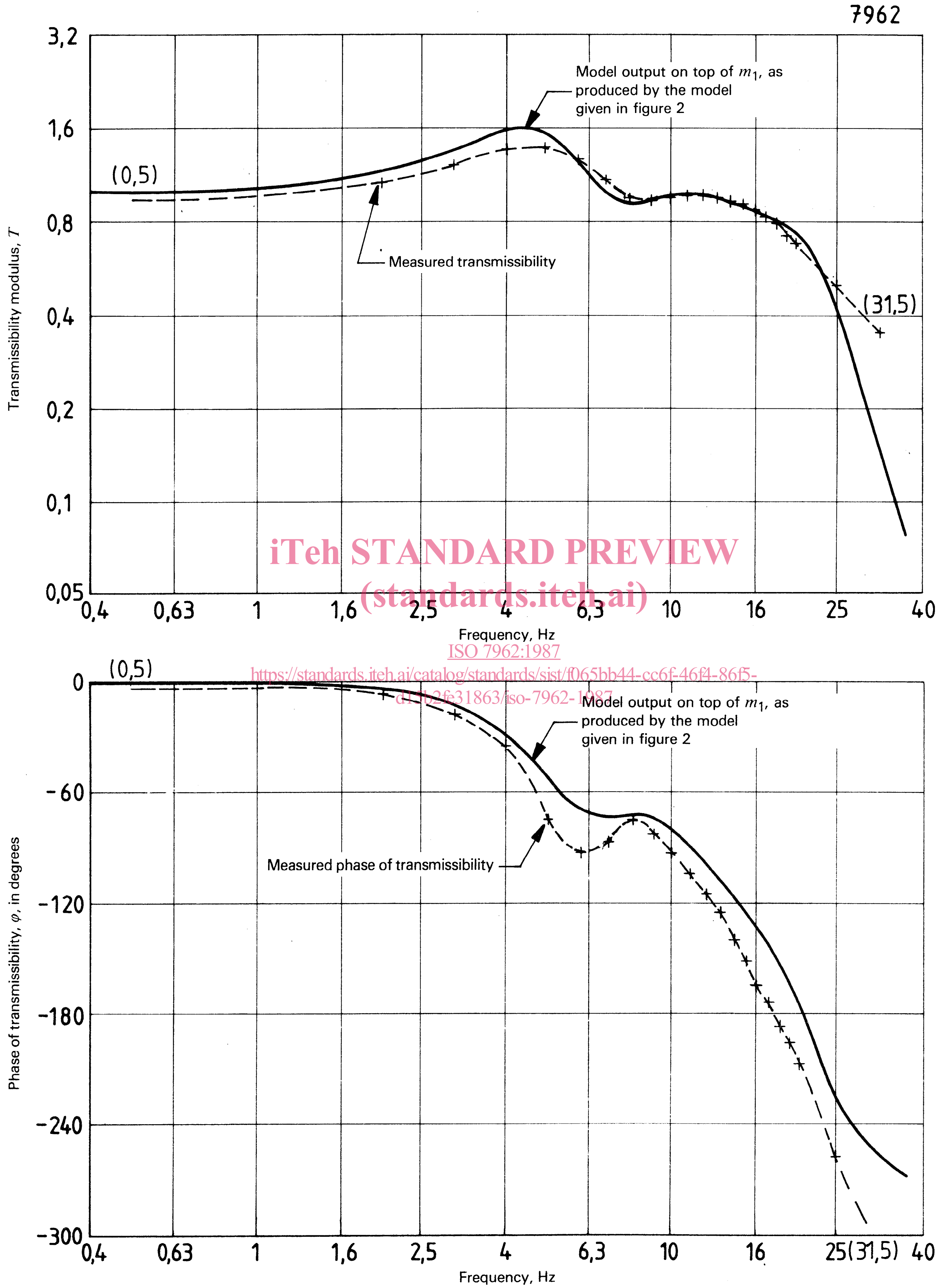
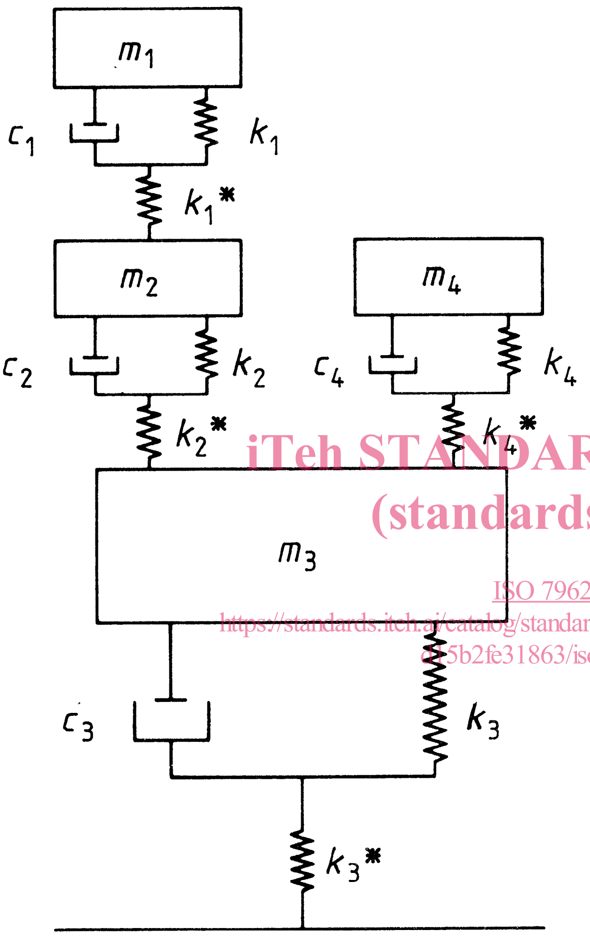


Figure 1 — Typical transmissibility of humans in sitting and standing erect postures



Model parameters	
m_1	8,24 kg
m_2	8,05 kg
m_3	44,85 kg
m_4	13,86 kg
k_1	22×10^8 N·m^{-1}
k_2	$20,13 \times 10^4$ N·m^{-1}
k_3	$88,56 \times 10^3$ N·m^{-1}
k_4	$36,47 \times 10^3$ N·m^{-1}
k_1*	36×10^7 N·m^{-1}
k_2*	65×10^9 N·m^{-1}
k_3*	$52,34 \times 10^4$ N·m^{-1}
k_4*	$69,30 \times 10^3$ N·m^{-1}
c_1	748,1 N·s·m^{-1}
c_2	578,0 N·s·m^{-1}
c_3	2 964,0 N·s·m^{-1}
c_4	901,8 N·s·m^{-1}

c dynamic viscosity

k, k* spring rate

m mass

Figure 2 — Proposed model for transmissibility along the z axis for sitting and standing positions

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