International Standard ISO 5982

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Vibration and shock — Mechanical driving point impedance of the human body

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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.

International Standard ISO 5982 was developed by Technical Committee ISO/TC 108, *Mechanical vibration and shock*, and was circulated to the member bodies in January 1979.

It has been approved by the member bodies of the following countries :

Australia	Germany, F. R.	Romania
Austria	Hungary	South Africa, Rep. of
Belgium	Italy	Spain
Brazil	Korea, Rep. of	Sweden
Chile	Libyan Arab Jamahiriya	Turkey
Czechoslovakia	Mexico	USA
Finland	Netherlands	USSR
France	New Zealand	Yugoslavia

The member body of the following country expressed disapproval of the document on technical grounds :

United Kingdom

Vibration and shock — Mechanical driving point impedance of the human body

0 Introduction

When considering the effects of shock and vibration on people, it is valuable to have an understanding of the mechanical characteristics of the body. This International Standard draws together available information on the input mechanical characteristics of the human body when subjected to vertical mechanical vibration.

1 Scope and field of application

This International Standard defines the mechanical characterics of the human body in the form of whole body mechanical input impedance. Available information is restricted to the frequency range from 0,5 to 30 Hz for a limited number of body positions.

It is expected that this impedance information will be used in the computer and analytical design of isolation systems such as platforms, seats and vehicle suspensions. Its use is limited to the development of mathematical models which represent the human body as a mechanical system. It should not be used to evaluate physiologic response or tolerance.

Mechanical systems should be designed to reduce detrimental vibration effects on the human body according to ISO 2631 and other associated documents.

It should be remembered that driving point impedance measurements are not necessarily the best approach if modelling of the complete (human) system is the intention. They can conceal remote resonances. The elements of any model derived may not represent the component parts of the human body.

2 References

ISO 2041, *Vibration and shock — Vocabulary.*

ISO 2631, *Guide for the evaluation of human exposure to whole-body vibration.*

3 Definitions

3.1 mechanical impedance : The complex ratio of force to velocity where the force and velocity may be taken at the same or different points in the same mechanical system during simple harmonic and steady state motion. Mechanical impedance can be extended to include transient and non-harmonic motion. It generally applies only to linear systems.

i.e. impedance is given by

$$Z(\omega) = \frac{F(\omega)}{V(\omega)}$$

where $Z(\omega)$, $F(\omega)$ and $V(\omega)$ are the complex values for impedance, force, and velocity respectively at a given frequency.

3.2 driving point impedance : Used when force and velocity are measured at the same point, whilst transfer-impedance indicates that the velocity is measured at a different point to the force input.

For simple harmonic motion, the impedance can easily be determined, in that the impedance magnitude is given by the ratio of the force and velocity sinusoidal amplitudes and the phase angle Φ is the phase difference between the force and velocity sinusoids. In the case of non-harmonic excited vibrations, the impedance is computed from the force and velocity spectra.

NOTE — If, in future, the dynamic characteristic of the human body is to be described as a multi-input system, the mobility-concept will be more suitable. The mechanical mobility is the inverse of the mechanical impedance.[5]

4 Human impedance

The impedance of the human body can only be described with certain reservations which are indicated below.

4.1 Frequency range

Impedance curves for the human body have been determined experimentally for frequencies up to 30 Hz.

4.2 Linearity

The human body vibrating in the z-axis (see ISO 2041) shows 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 impedance values as stated in the annexes.

4.3 Posture of the body

The impedance depends upon the body posture and muscle tension, which in turn are influenced by the specific activity of the human being. For example, the modulus of impedance and resonance frequency shift to higher values when the human body stiffens its spring characteristic by assuming an erect body position and/or muscle tensing : whereas the values decrease with a bent and relaxed position.

4.4 Body restraints

External restraints, such as seat pan and seat back orientation, arm or foot rests, seat-belts or harness will also affect the impedance of the body.

5 Presentation of the typical impedance curves of the human body

The whole-body z-axis input mechanical impedance of the human body seated or standing upright has the following general characteristics. Below about 2 Hz, the body vibrates like a pure mass. Above that frequency the impedance rises to a maximum in the region of 5 Hz, which is associated with the principal resonance of the human torso in response to z-axis excitation. At this point, for a constant input force of vibration, the response of the body is 1,5 to 2 times as great as would be that of rigid (i.e., non-resilient) mass under similar conditions of testing. Progressively, up to some 8 Hz, the response displays a spring-like characteristic. In the range 8 to 15 Hz, a second resonant response (local impedance maximum) is exhibited, while, at higher frequencies above 15 Hz, the response is essentially characteristic of a spring-damper combination.

In the supine position (x-direction) similar characteristics are exhibited with the first maximum located at approximately 7 Hz. The second maximum is not as clearly defined from the available data but is estimated around 30 Hz.

The values are derived from those which have been determined from available literature (see references in the annexes).

The curves represented in the following diagrams show the modulus and phase of the impedance of the human body in representative body positions in the frequency range between 0,5 and 31,5 Hz. The modulus is given in terms of $N \cdot s \cdot m^{-1}$.

The values presented are typical although based on a limited number of subjects. The available data is such that no conclusions can be drawn on changes in impedance with body weight or stature except below 2 Hz.

The upper and lower curves indicate the deviations due to intra-subject variability. These limits include approximately 80 % of available test results and midrange values were extrapolated to 0,5 Hz. In all cases, the values have been obtained from sinusoidal vibration of the body. Due to the possibility of non-linearities occurring, the curves from sinusoidal vibrations should not be taken to apply to other forms of motion. In general, the human responses are similar to those of a simple order system, with mass-like behaviour at low frequencies, a resonance range where the vibration force is greater than is the case with a rigid mass under similar conditions, and spring-like behaviour at higher frequencies. With each curve are the details of a simple model with a similar response. This information will need to be revised as further experimental evidence is produced.

Annex A

Driving point impedance — Standing position — z direction

Figure 1 gives a range of experimentally obtained values, together with the characteristics of a simple analogue with a similar response. The figure covers approximately 80 % of the range of experimental values obtained from available literature and relates to five subjects with a range of whole-body weights from 78,5 to 100 kg and sinusoidal acceleration amplitudes from 1 to 2,5 m/s^2. Subject posture was only loosely defined, for example "standing erect"[1] or "standing relaxed"[4].

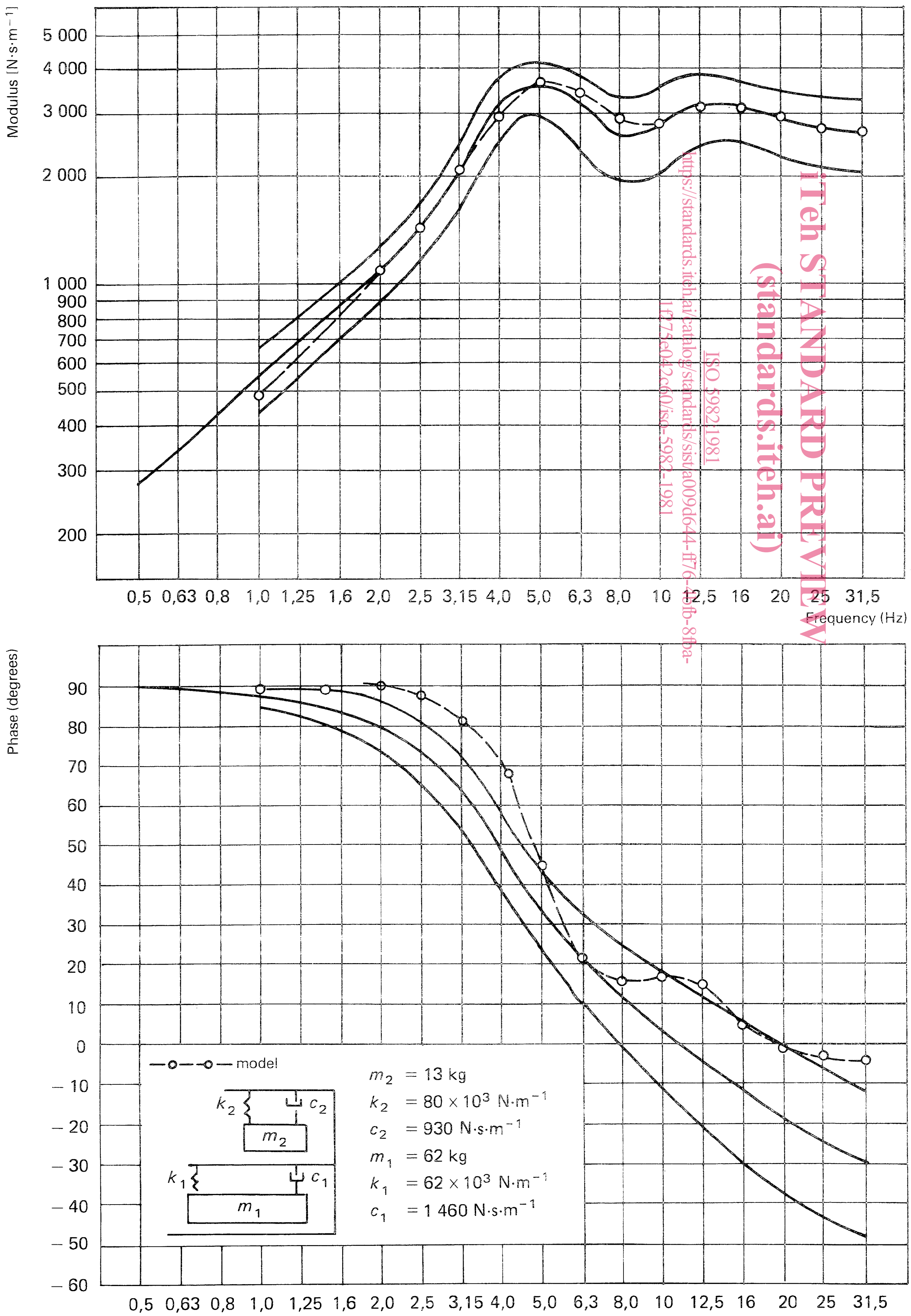

Figure 1 — Driving point impedance of human in standing position

Annex B

Driving point impedance — Sitting position — z direction

Figure 2 gives a range of experimentally obtained values, together with the characteristics of a simple analogue with a similar response. The figure covers approximately 80 % of the range of experimental values obtained from available literature and relates to thirty-nine subjects with a range of whole-body weights from 51 to 93,8 kg and sinusoidal input acceleration amplitudes from 1 to 2 m/s^2. (In some cases, however, the input acceleration was not given by the author.) The subject posture was usually poorly defined. In general, the values relate to an upright posture and for at least ten subjects, the feet were supported by a footrest moving with the seat. One would expect the impedance magnitude to be greater in those cases where the feet were not supported. The data cover a variety of restraint systems, although the seat surfaces were rigid and flat.

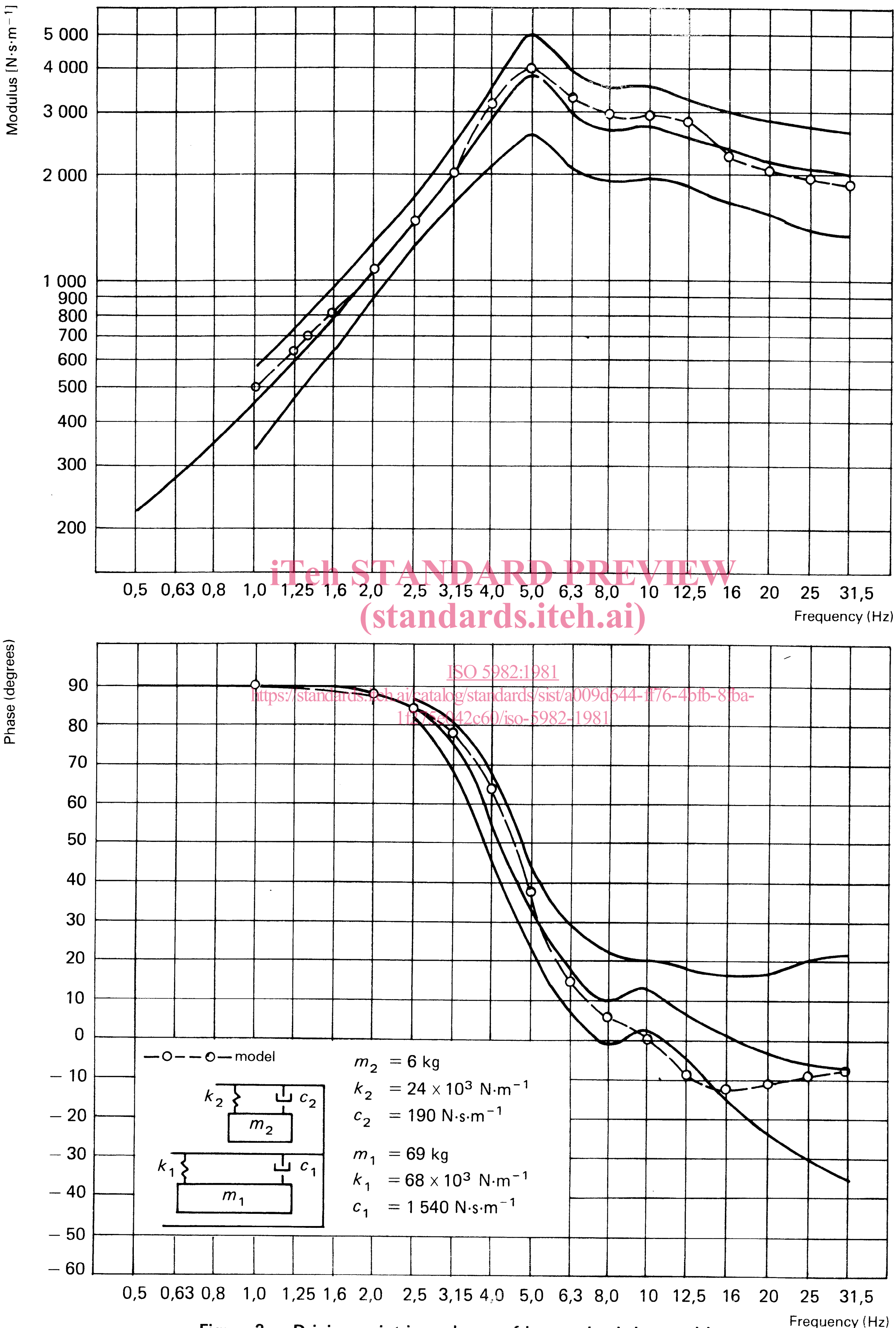

Figure 2 — Driving point impedance of human in sitting position

Annex C

Driving point impedance — Supine position — x direction

Figure 3 gives a range of experimentally obtained values, together with the characteristics of a simple analogue with a similar response. The figure covers approximately 80 % of the range of experimental values obtained from available literature and relates to twelve subjects with a range of whole-body weights from 62,2 to 104 kg and sinusoidal input acceleration amplitudes from 1 to 2,5 m/s^2. Subjects were not asked to control muscle tension. The supporting surfaces were rigid and flat.