

Guide to

Safety aspects of experiments in which people are exposed to mechanical vibration and shock

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Foreword

This British Standard Guide has been prepared under the direction of the General Mechanical Engineering Standards Policy Committee.

Although information about human tolerance and safe exposure to mechanical vibration and shock is incomplete, there is sufficient agreement to enable useful guidance for future experiments involving such exposure to be included in this standard.

This British Standard supersedes DD 23:1973 which is withdrawn, and should be read in conjunction with BS 6841.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 16, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

0 Introduction

People may be exposed to mechanical vibration and shock intentionally in the course of experiments to determine their response to such environments and in the course of experiments or tests performed for other purposes. It is widely accepted that exposure to mechanical vibration and shock of sufficient magnitude can cause injury or impair health.

In this standard, tentative guidance is provided on the safety aspects of equipment or procedures which are particular to experiments involving mechanical vibration and shock and which affect the safety of those involved.

The purpose of this standard is to reduce the chance of the subjects or those monitoring or conducting the experiments being exposed to undue risk of injury or impaired health arising from such exposure, or of injury attributable to the malfunction or maloperation of the equipment used to generate the mechanical vibration and shock.

1 Scope

This British Standard provides guidance on safety aspects of the design of equipment and the conduct of experiments in which human test subjects¹⁾ are exposed to mechanical vibration and shock.

The guidance relates mainly to the design and operation of equipment for laboratory experiments. However, it could apply also to other situations in which subjects are exposed to mechanical vibration and shock. Clauses 3 and 8 respectively, concerned with the definition of magnitudes of exposure and the selection of subjects, are equally applicable to experiments in which the mechanical vibration or shock is generated in the course of field trials, e.g. by the passage of a vehicle over rough ground.

This standard is concerned with experiments in which subjects are exposed to whole-body mechanical vibration and shock. Local vibration is not within the scope of this standard but some of the general procedures may be applicable.

The experiments to which this standard is applicable include those performed to determine the response of subjects to mechanical vibration and shock stimuli. They also include those experiments in which mechanical vibration or shock are part of the environment in which other investigations are performed, and to experiments or tests to compare the attributes of equipment intended to alleviate the effects of mechanical vibration or shock on the user, e.g. tests to BS 4220.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

¹⁾ Hereinafter referred to as "the subject".

2 Definitions

For the purposes of this British Standard, the definitions given in BS 3015 apply.

3 Hazards of mechanical vibration and shock experiments on human test subjects

3.1 General

Those who engage in experiments which involve exposing subjects to mechanical vibration and shock, and those who supply equipment for such experiments, should address three types of hazard specific to such experiments, in addition to the general responsibility for safety, as follows:

- a) the inherent risk that exposure to the mechanical vibration or shock which the experiment is intended to reproduce may lead to injury or ill-health, either immediately or at some time in the future (see 3.2);

NOTE See Appendix A of BS 6841:1987.

- b) the extraneous risk that malfunction or inadvertent operation of the equipment used to generate the mechanical vibration or shock may cause the subject to be exposed unintentionally to motions so severe as to cause injury or ill-health;

- c) the risk of injury to the subject, the experimenter, or others in the vicinity arising from any of the following:

- 1) the relative motion between the vibration equipment and its surroundings;
- 2) mechanical or other failures;
- 3) falling.

3.2 Inherent risks in mechanical vibration and shock experiments

The inherent risk that exposure of a subject to mechanical vibration or shock may lead to injury or ill health depends on the following two possible causes:

- a) using mechanical vibration or shock that is too severe in terms of magnitude or duration;

NOTE Information about magnitudes of mechanical vibration or shock is given in 3.3.

- b) failure to exclude from the test a subject who is medically unfit or otherwise particularly sensitive to mechanical vibration or shock.

NOTE Precautions to be taken with subjects are given in clause 8.

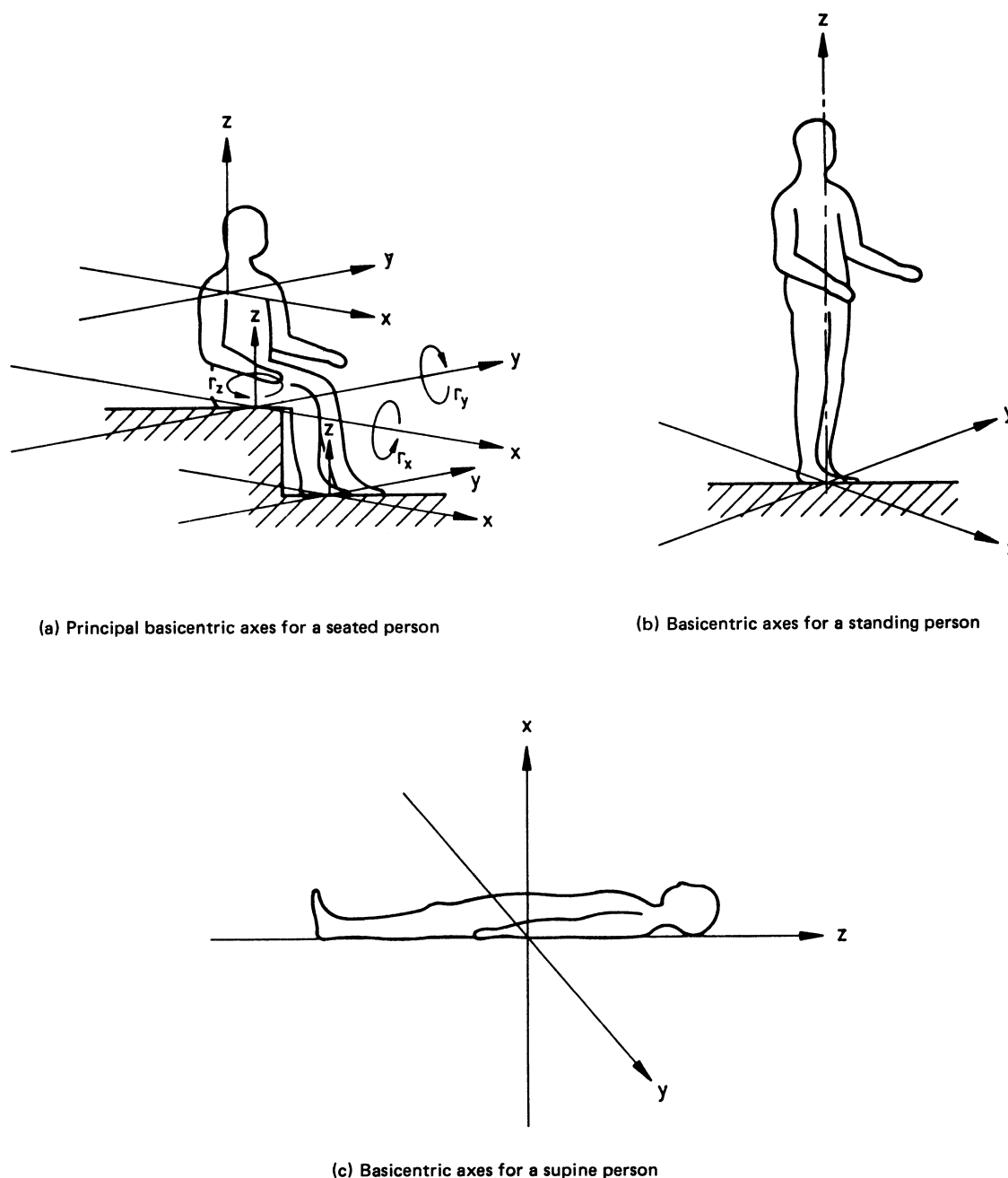


Figure 1 — Basicentric axes of the human body

3.3 Severity of mechanical vibration or shock stimulus

The effects on subjects of mechanical vibration and shock depend on the magnitude, frequency content, direction of action and duration of the stimuli, all of which should be included in assessing the severity.

In all cases the mechanical vibration is to be measured at the interface of the subject with the vibrating surface in accordance with BS 6841. Vibrations may be characterized as periodic or random and for the purpose of this standard are restricted to frequencies between 0.5 Hz and 80 Hz. Shocks may be applied with or without the presence of vibration, with various characteristics and may be applied singly or repetitively.

Mechanical vibration and shock should be characterized from measurements of acceleration in three mutually perpendicular axes, with the addition of a fourth measurement, for seated subjects, of the fore-and-aft (x-axis) acceleration at the interface with the backrest in accordance with A.5 of BS 6841:1987 (see Figure 1).

Frequency weighting functions which reflect the different sensitivities of subjects to vibration stimuli with different axes are given in Appendix A.

The use of these weighting functions enables exposure to continuous sinusoidal or random mechanical vibration, which is statistically stationary, to be assessed simply in terms of the r.m.s. value of frequency-weighted acceleration and its duration. Exposure to mechanical vibration, whose characteristics vary with time, and to mechanical shock, may be assessed in terms of a vibration dose value VDV (in $\text{m s}^{-1.75}$) which is calculated from the following equation:

$$\text{VDV} = \left(\int_0^T a^4(t) dt \right)^{1/4}$$

where

$a(t)$ is the frequency-weighted acceleration (in m s^{-2});

T is the total period of exposure (in s).

For mechanical vibrations which are statistically stationary the estimated vibration dose value eVDV (in $\text{m s}^{-1.75}$) may be approximated from the following equation (see A.4 of BS 6841:1987):

$$\text{eVDV} = \{ (1.4a)^4 t_0 \}^{1/4} = 1.4at_0^{1/4}$$

where

a is the r.m.s. value (in m s^{-2});

t_0 is the duration (in s).

For mechanical vibration which comprises significant components in more than one direction, a total vibration dose value can be calculated as the fourth root of the sum of the fourth powers of vibration dose values in each axis. Alternatively, where r.m.s. values have been calculated, a convenient approximation to the total vibration magnitude may be determined as the square root of the sums of the squares of the individual r.m.s. components (see Table 1).

Table 1 — Weighted acceleration equivalent to a vibration dose value of $15 \text{ m s}^{-1.75}$ for continuous mechanical vibration at constant magnitude

Duration of exposure	1 s	4 s	16 s	1 min	4 min	16 min	1 h	4 h	8 h
Weighted acceleration, r.m.s (in m s^{-2})	10.71	7.57	5.36	3.84	2.72	1.92	1.38	0.98	0.82

3.4 Extraneous risks in mechanical vibration and shock experiments

3.4.1 Equipment malfunction. Many vibrating devices used in experiments have a large quantity of available or stored energy. An inherent problem in the design of vibration systems is that the subject may be exposed to unexpected or frightening transients, or at worst, to potentially dangerous magnitudes of mechanical vibration or shock as a result of a malfunction.

In shock experiments, the subject is either brought suddenly to rest after slow acceleration to a specified velocity, or accelerated suddenly from rest. There is an attendant risk that equipment malfunction could lead to dangerous magnitudes of shock.

Equipment design should be such that, in the event of malfunction or emergency stop procedures, the subject should not be exposed to changes in the force environment of hazardous intensity or duration. Equipment should be designed so that no failure could result in magnitudes of mechanical vibration or shock producing vibration dose values in excess of $15 \text{ m s}^{-1.75}$, unless the experiment is designed to study the effects of higher magnitudes. For such experiments, the magnitude during failure conditions should be only slightly in excess of those being studied.

3.4.2 Physical contact with moving parts.

Mechanical vibration and shock experiments present the following three particular physical hazards:

- a) the experimenter or another person in the vicinity of the equipment may receive a blow through inadvertent contact with the moving parts;
- b) the subject on a moving part may receive a blow through inadvertent contact with a fixed object;
- c) anyone on the equipment or in the vicinity may be at risk from pinching or shearing between fixed and moving parts.

NOTE The principles of machinery safeguarding are covered in BS 5304.

3.4.3 Subjects' restraint. In experiments where subjects are restrained, special care should be taken to ensure that during normal operation or malfunction any restraint does not present a hazard.