BRITISH STANDARD

PD 6585-2 : 1996
CR 1030-2 : 1995

Hand-arm vibration — Guidelines for vibration hazards reduction

Part 2. Management measures at the workplace

British Standards

Committees responsible for this Published Document

The preparation of this Published Document was entrusted to Technical Committee GME/21, Mechanical vibration and shock, upon which the following bodies were represented:

Federation of Civil Engineering Contractors
Imperial College of Science and Technology
Institute of Sound and Vibration Research
Institution of Mechanical Engineers
Lloyd's Register of Shipping
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The following bodies were also represented in the drafting of the Published Document, through subcommittees and panels:

Agricultural Engineers Association
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University of Salford

This Published Document, having been prepared under the direction of the Engineering Sector Board, was published under the authority of the Standards Board and comes into effect on
15 April 1996

The following BSI reference relates to the work on this Published Document:
Committee reference GME/21

ISBN 0 580 25152 7

Amendments issued since publication

Amd. No.	Date	Text affected

Contents

National foreword

This Published Document which has been prepared by Technical Committee GME/21 is the English language version of the CEN Report CR 1030-2 : 1995 *Hand-arm vibration — Guidelines for hazards reduction — Part 2 : Management methods at the workplace.*

Cross-references

Publication referred to	Corresponding British Standard
CR 1030-1 : 1995	PD 6585 *Hand-arm vibration — Guidelines for vibration hazards reduction* Part 1 : 1995 *Engineering methods by design of machinery*
EN 28662-1 : 1992	BS EN 28662 *Hand-held portable power tools. Measurement of vibrations at the handle* Part 1 : 1993 *General — Specifies the test methods for power driven tools. This part describes the basic requirements for evaluating vibrations*

REPORT

RAPPORT

BERICHT

CR 1030-2

June 1995

English version

Hand-arm vibration — Guidelines for vibration hazards reduction — Part 2: Management measures at the workplace

Vibrations main-bras — Guide pour la réduction des risques de vibrations — Partie 2: Measures de prévention sur le lieu de travail

Hand-Arm-Schwingungen — Leitfaden zur Verringerung der Gefährdung durch Schwingungen — Teil 2: Oganisatorische Maßnahmen am Arbeitsplatz

This CEN Report has been prepared by Technical Committee CEN/TC 231, Mechanical vibration and shock, and has been approved by CEN on 1995-04-05.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. CR 1030-2 : 1995 E

Foreword

This CEN report has been drawn up by CEN/TC 231, Mechanical vibration and shock, working group 2, Hand-arm vibration.

Contents

Introduction

The habitual and prolonged use of machinery which transmit vibration to the hand may cause disorders of the upper limbs.

European legislation requires firms to assess and take measures to prevent or reduce workplace risks to the health and safety of their employees. The basic strategy to be adopted is defined in the legislation and accompanying informative documents under the following broad headings:

- assessment of risks;
- identification of necessary preventative and/or protective measures;
- organization for the effective implementation of preventative and protective measures;
- implementation of an adequate programme of measures to prevent or reduce risks.

This document is primarily concerned with the second item. Its purpose is to bridge the gap between the existing literature on vibration control and the practical implementation of vibration control measures. It will constitute brief guidance to managers, health and safety officers, engineers, planning and purchasing staff and others on the most important aspects of vibration effect reduction and control.

To reduce the vibration stress for the user it is essential to pay attention not only to the vibration intensity itself but also to the coupling of the machine to the hand-arm system and to the exposure duration. All three parameters can be influenced by technical measures.

Effective protection against vibration will generally require a combination of measures which can be categorized under the following headings:

- engineering measures;
- personal protection;
- management measures.

The application of these measures should take account of: the state of the art regarding technical progress, the availability of practicable vibration reduction and the compatibility of proposed vibration control measures with measures required to reduce or control other workplace hazards.

1 Scope

These guidelines outline practicable measures for the reduction and control of health hazards associated with exposure to hand-arm vibration at work in order to provide practical professional aid to managers and health and safety officers. The document covers four principal aspects, namely:

- identification of main sources of hand-arm vibration within the firm;
- vibration reduction by re-considering task, product, and process and re-design;
- how to select low vibration machinery, anti-vibration system and personal protection;
- management measures for the control of hand-arm vibration exposure.

2 Normative references

This CEN report incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this CEN report only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

CR 1030-1	*Hand-arm vibration — Guidelines for vibration hazards reduction — Part 1: Engineering methods by design of machinery*
CR (X)[1]	*Mechanical vibration — Guidelines to health effects of vibration on the human body*
prEN 1033	*Hand-arm vibration — Laboratory measurement of vibration at the grip surface of hand-guided machinery — General*
EN 28662-1	*Hand-held portable power tools — Measurement of vibrations at the handle — Part 1: General (ISO 8662-1 : 1988)*
prEN 30819	*Mechanical vibration and shock — Hand-arm vibration — Method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand (ISO/DIS 10819 : 1993)*
ISO 5805	*Mechanical vibration and shock — Human exposure — Vocabulary*

[1]Under preparation.

3 Definitions

Except where otherwise stated, technical terms used in this document are as defined in ISO 5805.

4 Identification of main sources of hand-arm vibration within the firm

In addition to general knowledge about hand-arm vibration, its effects on man and its assessment and control, it is essential that the nature of hazard within the firm be well understood, i.e. that the various sources and their characteristics are known, exposed employees identified and the magnitude of the risks quantified.

In order to do this it will be necessary to know:

- legal requirements including 'action levels' or exposure limits (see annex A);
- the machinery, processes, tools and tasks in use within the company which are likely to expose employees to vibration.

NOTE 1. An 'action level' represents the conditions under which the situation may become a cause for concern, which will justify specific action, at the least closer examination of the specific situation.

An initial identification of sources of exposure to hand-arm vibration can be made by listing all the vibrating processes, machines and tools used within the firm which require employees to hold or guide a vibrating handle, control, workpiece or other vibrating surface. A list of the more common machines and processes which expose people at work to hand-arm vibration is given in annex B.

Furthermore, it is necessary to know:

- the number and location of employees for each of the tasks which expose them to hand-arm vibration;
- representative vibration values for each machine, tool, etc., which create the hazard and the vibration exposure of persons at risk.

The assessment of human exposure to hand-arm vibration requires a knowledge of the vibration values to which people are exposed and of the daily duration of vibration exposure.

Also important is:

- the contribution made by each source of vibration to the total vibration burden (TVB) of a person.

TVB represents the contribution of a particular machine, process or tool to the daily vibration exposure of the persons who operate or use it. It is derived by summing their fractional vibration exposures, i.e. the ratios of the actual daily vibration exposure associated with each individual's use of the machine or tool to a reference value. The most appropriate reference value might be the first (or lowest) 'action level' specified in relevant legislation or guidelines.

The values derived in this way show which tools and processes impose the greatest total vibration burden on the workforce and this could be taken into account when deciding priorities for action.

NOTE 2. It is recognized that the measurement and assessment of vibration may be complex and may require costly equipment; it will generally be necessary to use the service of a competent vibration consultant. Therefore, in some cases it may be practicable to estimate vibration exposures, without making measurements of vibration values, by using vibration data provided by machinery suppliers (EC machinery directive 89/392/EEC makes vibration declaration compulsory for a great variety of industrial machinery) or published in the technical literature and production data concerning the tasks carried out by exposed employees.

The daily exposure (normalized to a standard reference period of 8 h) associated with the use of a machine can be roughly estimated for each operator from the following equation:

$$a(8) = a_{h,w} \left(\frac{T}{8}\right)^{1/2}$$

Where $a_{h,w}$ is the frequency weighted r.m.s. acceleration in m/s^2 provided e.g. by machinery suppliers, and T in hours, the exposure required.

5 Vibration reduction by task, product and process re-design

5.1 General

Detailed information should be gathered concerning the usage of the various machines, processes and tools which have been identified as sources of a hand-arm vibration hazard: i.e. what they are used for, how they are used and why they are used.

In considering a particular production function or task, the first step would be to define its purpose or function in broad terms, i.e. what is to be achieved or done. At this stage the question as to whether or not the function provided by the process is required at all should be reviewed and to do this it will be necessary to consider all the factors which created the need for the function or task. Some of these factors may, however, be outside the firm's control e.g. customer's requirements, an architect's design or a consultant's recommendation.

The second step is to break the process down into its key elements, processes or stages, highlighting those which are the principal contributors to the vibration hazard. (There may, of course, be other hazards such as physical strain or noise, which may also need to be dealt with.) This should then be used for a systematic analysis to determine the most cost-effective combination of protective and preventative measures.

The basic methods for reducing occupational exposure to hard- arm vibration are in order of priority:

a) elimination of hazard by the substitution of alternative non-hazardous processes, machinery or plant, e.g. automated or mechanized processes;

b) reduction of vibration at source by machinery or process modification, e.g. the use of low vibration equipment, where a) is not reasonably practicable;

c) reduction of vibration transmission

– in the path between the source of vibration and the handles or other vibrating surfaces gripped by employees' hands,

– from handles and other vibrating surfaces onto the hands gripping them;

d) reduction of exposure duration, e.g. work rotation to reduce the time for which employees are actually in contact with tool handles, machine controls, or other vibrating surfaces.

These measures may be practicable at any or all phases of a particular work operation or task. Annex C provides a practical example of how the method works.

5.2 Vibration reduction by work task re-design

The risks to the health of persons who are exposed to hand-arm vibration can be reduced by adapting work tasks to the individual.

Work tasks should be designed so that (see CR (X)):

– the values of hand-arm vibration are as low as practicable;

– the daily period of exposure to hand vibration is as short as possible;

– the working posture is one which imposes the least physical burden on the individual;

– physical loads, particularly (but not only) those on the hand-arm system, are matched to the capabilities of the individual;

– unduly rapid and frequent repetition of finger, hand and/or arm movements are avoided.

In designing the work task, it must be noted that the greater the forces applied by the hand upon vibrating surface, the greater the vibration passing into the user's hand and arm.

Detailed guidance on machinery design is given in CR 1030-1.

5.3 Vibration reduction measures by product re-design

All involved in the process, customers, designers, production engineers and managers, should take into account certain 'essential safety requirements' relating to the potential impact of the product on the health and safety of those who are involved.

In respect of hand-arm transmitted vibration, product designers should evaluate the effect of alternative designs on the manufacturing process in general and the ergonomic requirements of work tasks.

Where appropriate, the advice of production engineers, production managers, vibration and other specialists should be sought. In particular the aim should be:

– to avoid or at least minimize the use of operations and tools which expose workers to hazardous values of vibration;

– to facilitate the use of low vibration tools or processes;

– to facilitate the optimum ergonomic design of work spaces and tasks.

Practical examples are given in annex D.

5.4 Vibration reduction by process re-design

Where employees are exposed to hand-arm vibration a thorough re-appraisal of the production process or task should be carried out and where reasonably practicable, alternative low vibration processes substituted for those which create the hazard.

Often ways of improving the process will be found which not only reduce hazardous vibration (and possibly other hazards) but also improve productivity and quality.

Practical examples of vibration reduction measures by process design are given in annex E.

Some of the more obvious possibilities for vibration reduction by use of an alternative process are as follows:

– the substitution, where practicable, of milling, turning or other machining operations for metal removing processes which used powered hand tools, such as portable grinders and pneumatic chisels;

– the use of arc-air and other flame cutting or gouging methods instead of pneumatic chisels or portable grinders for the rough dressings of castings and similar work;

– the use of smooth hydraulic rather than pneumatic, impulsive, or riveting techniques.

Sometimes the alternative process may not be a complete substitute for processes which expose workers to vibration but nevertheless might reduce substantially the total vibration exposure by reducing the extent to which such processes are used.

Abrasive, mechanical cleaning or mixed mechanical and chemical cleaning processes, such as shot blasting and rumbling can be substituted for grinding and descaling operations. Where the process involves the removal of rust and paint, abrasive or mechanical cleaning will generally be more effective and economic than grinding.

Where elimination or substitution is not reasonably practicable, it may, nevertheless, be possible to re-design the process so as to eliminate many hazardous, manual operations by the greater use of mechanization and remote control or automation.

NOTE. Care should be taken to ensure that the removal of one hazard does not introduce one that is worse.

6 How to select low vibration machinery, anti-vibration systems and personal protection

6.1 Selection of low vibration machinery

6.1.1 *General*

When the use of powered hand-held or hand-guided equipment is unavoidable, vibration exposure can be minimized by careful selection of the machinery or tools to be used.

Many manufacturers of hand-held or hand-guided machines thus now market one or more low vibration designs, e.g. breakers, grinders, hammers, chipping hammers, sanders, lawn mowers, hedge shears, impact wrenches, chain saws, needle scalers. Annex F gives practical examples of vibration reduction by selection of machinery or equipment.

In practice some difficulty may be experienced in choosing a low vibration machine because of a lack of appropriate test codes and the current inadequacy of available information on machine vibration emissions.

6.1.2 *Questions that potential buyers should ask themselves*

Before purchasing new machinery or equipment, potential buyers should always ask themselves the following basic question:

- is adequate information (vibration declaration) available about the vibration of that machine family and about the lowest vibration achievable?

According to the EC machinery directive 89/392/EEC manufacturers and suppliers of equipment for use at work have a duty to provide adequate information about the articles they supply and in particular about any conditions necessary to ensure safe use without risk to health. Where the weighted r.m.s. acceleration measured in an appropriate standard test exceeds 2,5 m/s^2, the weighted r.m.s. acceleration shall be given in the instruction book.

Further questions of importance are:

- has a specific request for information or guarantee on vibration been included in the tender specification to potential suppliers, and is the request properly formulated?
- what will be the vibration impact of the new machine on the workshop where it will operate?

On the basis of these considerations, a purchasing policy should be developed with respect to vibration requirements:

- look carefully at the vibration information available for the workplace where the machine will operate, or if it does not exist yet (planning stage), for another workplace with similar industrial activity;
- look carefully at the vibration information that may already be available in the company for similar machines;
- consider the vibration limits applicable to the workplace concerned, and the vibration limits for the machine;
- examine the long term vibration reduction programme of the company;
- determine what vibration information and, optionally, what compliance with a vibration requirement can reasonably be requested from potential suppliers, taking into account technical usefulness and practicability. This may imply an interaction between several parties inside and outside the company and a dialogue with potential suppliers;
- consider what this vibration information means, how can it be used and for which purposes;
- choose the machine with the lowest possible vibration value.

Annex G provides a list of the most important questions with regard to hand-arm vibration that potential buyers should ask suppliers.

6.1.3 *Declared vibration values*

Values of machine vibration are given by the manufacturer in the vibration declaration. The method and procedure to verify these values are defined in EN 28662-1 and EN 1033.

Declared vibration values are intrinsic characteristics of a machine and shall only be used as such. In particular, there is no unique and simple relationship between the declared vibration values for a machine and the values which will be encountered when the machine is in operation in a workshop.

NOTE. Additional vibration data may also be provided in the vibration declaration. This may be information that has been estimated, calculated or measured in various operating conditions, test environments, etc. Additionally to the declared vibration values, a potential buyer may ask a supplier to guarantee that a given vibration value at defined measurement position and for defined operating conditions of the machine shall not be exceeded once the machine is in operation. This implies a close collaboration and a technical dialogue between the various parties involved inside and outside the company.

The buyer of a machine may wish to check whether or not the vibration values given in the vibration declaration provided by the supplier are exceeded and/or that a specific vibration requirement is met.

6.2 Selection of anti-vibration system and personal protection

6.2.1 *General*

If workers are still exposed to excessive vibration when all practicable measures to minimize contact between hands and vibrating surfaces and to reduce vibration at source have been taken, then anti-vibration systems may be useful.

Direct connection between workers' hands and vibrating surfaces can often be avoided by making use of jigs, and similar aids which incorporate anti-vibration mounts or other means of preventing vibration from reaching the users' hands.

However, providing effective vibration isolation between the vibrating surfaces of machines or components and the hands of persons at risk, may be difficult especially for tools which vibrate at low frequency.

The resonance frequency of a suspension system must be lower by at least a factor of 1,4 than the lowest significant vibration frequency, otherwise there will be a risk of amplification of the vibration transmitted to the user.

6.2.2 *Anti-vibration handles*

Manufacturers of some portable power tools fit 'anti-vibration' handles to their products.

In some cases it may be possible to fit 'anti-vibration' handles to tools retrospectively, but care should be taken to ensure that the handle selected is properly matched to the vibration characteristics of the tool, or the situation may be made worse rather than better.

Because of the need to ensure that the operator has adequate control of the machine and also to guard against the possibility that handle failure might expose a machine user to risk of injury, handle selection will be a compromise, with isolation effectiveness being traded off against controllability and safety.

6.2.3 *Use of resilient materials*

The wrapping of rubber or specially developed resilient materials around vibrating handles, or other hand-held vibrating surfaces may reduce the high frequency vibration transmitted to the hands (above 200 Hz). In general, however, such action is unlikely to reduce significantly the transmission of vibration in the range of frequencies which are important with regard to the development of vibration-induced white finger (VWF) and other vibration related symptoms.

Sleeves of resilient materials have been fitted to the chisels of pneumatic hammers. The makers claim that attenuation of vibration down to a frequency of 160 Hz has been obtained and the sleeves have proved acceptable to the workers concerned. They also claim that, if used in combination with suitable gloves, improved attenuation can be obtained. Composite sleeve designs, in which the resilient material is contained within a steel tube, can provide better attenuation at low frequencies. The performance depending on the mass of the tube and the hardness, thickness and form of the resilient core.

6.2.4 *Reduction of forces exerted by operators*

These forces may be required in order to:

a) support the weight of a tool or workpiece;

b) control and guide a machine, tool or workpiece;

c) achieve and maintain high metal removal rates.

The actual forces applied may differ from the minimum values required due to:

- the incorrect selection of equipment for particular tasks;
- inadequate maintenance;
- inadequate operator training;
- poor workstation design.

Vibration transmission to the hands can, therefore, be reduced by measures which reduce these forces. Some possibilities are outlined below.

At pedestal grinders, arrangements can sometimes be made to provide support for the workpiece so that the worker need only guide the article onto the wheel rather than support its whole weight. Tension chains (sometimes called balancers) and manipulators can be used to support vibrating tools, such as heavy drills, nut runners, nailing guns and (in some cases) pneumatic chisels, thus eliminating the burden imposed by the tool's weight and reducing the vibration energy passing into the user's hand and arm.

Changes in the texture and material of a grip surface may help the operator to use a lighter grip to hold and control the tool.

NOTE. Heated handles should be considered for hand-held or hand-guided machines (for example chain saws) whose principal use is outdoors or in other low temperature environments.

6.2.5 *Personal protection*

For some occupational health hazards, such as noise, workers can obtain satisfactory protection from appropriate personal protection provided it is properly selected, used and maintained. This is not true, however, for the hazards which are caused by the exposure of worker's hands to vibration. Research has shown that most gloves provide little attenuation of vibration at the most hazardous frequencies and in some cases may increase the value of vibration reaching the hand.

Further development by glove manufacturers may result in the production of gloves which provide some attenuation of vibration down to frequencies of around 200 Hz and these may be of value in some applications. However, generally, the lower the frequency at which attenuation is required the thicker the resilient padding needed in the contact areas of the glove and the less acceptable the glove to the employees affected. In some cases the reduced feel for the tool or workpiece may cause the employee to tighten his or her grip, thus increasing the vibration transmission from the handle to the hand.

Gloves may, however, have to be worn in order to provide physical protection against impacts, sharp edges, hot surfaces or for other reasons. In cold environments the wearing of suitable gloves may, by keeping the hands warm, inhibit development of vibration-induced white finger in persons exposed to hand-arm vibration.

Where practicable such gloves should be selected so as to ensure that they do not significantly increase the vibration transmitted to the wearer's hands. In some cases it may be possible to select gloves which attenuate at least the higher frequencies in the range to which the human hand-arm system is susceptible.

Glove suppliers should be requested to provide vibration transmissibility data obtained from tests carried out in accordance with EN 30819.

7 Management measures for the control of hand-arm vibration exposure

7.1 Hazard reduction strategy

The prevention and reduction of vibration exposure is the key element of the risk management programme which must, under European legislation, be applied in firms where people are exposed to hand-arm vibration. A systematic approach is essential if the risks associated with exposure to hand-arm vibration are to be reduced by engineering and organizational means, in a cost-effective manner.

The basic strategy could be:

- to identify the main sources, their nature and severity of hand-arm vibration within the firm;
- to establish broad policy, overall aims and priority of actions with respect to the management of health risks associated with exposure to hand-arm vibration.

This should include an explicit purchase philosophy favouring of the purchase of low vibration tools.

It is important that vibration hazard policy is supported at the highest managerial level. Without such support, it may not be possible for those at other decision making levels in the organization to reconcile budgetary and profit requirements with those of vibration hazard policy.

Furthermore, it is an important basic strategy:

- to analyse all the stages and factors contributing to the creation of vibration hazardous tasks to select the optimum measures to reduce vibration.

In order to specify precise target values it is necessary to know what might be achieved by applying state of the art measures for the reduction of vibration exposure and at what cost.

Many of the tasks which expose employees to vibration will be carried out as part of a manufacturing or production process, for maintenance purposes, or, in some cases, as part of a service activity, e.g. motor cycle delivery services. All the stages leading up to the selection and use of particular processes, machines and tools which contribute to the creation of vibration hazardous tasks should be re-considered.

It is important that all managerial and technical decisions, and actions which may influence hand-arm vibration hazards in the workplace are thoroughly scrutinized to determine their likely impact and where possible, enable improved decisions to be made.

The results of this analysis should then be used:

- to prepare and implement a programme of risk reduction and control measures;
- to maintain positive motivation in both the managers responsible for taking action and in persons at risk;
- to ensure the effectiveness of the vibration hazard reduction programme;
- to maintain the effectiveness of any long term risk management system.

7.2 Process control and maintenance

Good process control is not only important as a means of maintaining product quality and production efficiency but also as a means of reducing vibration hazards. In the ship building and ship repair industries, vibration exposure can be reduced by establishing good quality control systems which avoid mistakes and subsequent rectification work.

Vibrating tools and other equipment which expose workers to hand-arm vibration should be serviced on a regular basis. The suppliers of the equipment should be able to provide suitable maintenance schedules but these may need to be supplemented by additional instructions to take account of the effects of tool or equipment use in particular applications.

A scheme of preventative maintenance should also be established for components, attachments and other devices provided to reduce worker vibration exposure, e.g. anti-vibration handles, anti-vibration mounts.

Annex H provides a list which indicates a few of the measures that should be taken to maintain tools and equipment correctly.

7.3 Training

When recruited, it is important that each worker should be provided with relevant information, instructions and training specific to the work tasks he or she is expected to carry out. This will need to be repeated periodically to take account of:

- changes in the work tasks being carried out; and
- changes in machinery, plant or processes.

The aim of the training is to ensure that:

- work tasks are carried out in such a way that the health risks arising from exposure to hand-arm vibration are minimized;
- personal protective equipment is correctly used;
- the risks, and ways in which individuals at risk can contribute to their reduction and control, are understood;
- workers exposed to hand-arm vibration are positively motivated to cooperate with their managers in combating the health risks.

With regard to hand-arm vibration, grip force, feed force, position of hand and posture greatly influence the vibration energy transmitted into the hand and arm. The best working technique should be identified and employees given appropriate instruction and training. Training in good working practice also ensure that the weight supported by the operator's hands is as low as possible. This requires the worker to rest the tool as much as possible on the material being worked (or in the case of hand-held workpieces, on any support provided) and to hold it with a light but safe grip.

In some cases it may be difficult to get worker acceptance of new tool and methods especially where incorrect working practices, which have become deeply ingrained throughout years of use, have to be altered. For example, training workers who use pedestal grinders to avoid the common practice of placing their hands between the work rest and the workpiece during grinding and sometimes during dressing.

Unbalance is sometimes deliberately created in hand-held grinders by the practice of bending the shaft of mounted points. This is not only bad for the tool used but also for the tool user, and should be eliminated by appropriate instruction and training supplemented by effective supervision and control of the process.

Differences in the weight of portable tools and changes in the sensations of vibration experiences often cause users of low vibration tools to reject them because they feel that they are not doing the job as well as the tools they have become accustomed to.

7.4 Reducing the period of exposure

Initially, while methods of vibration reduction are being developed and where all reasonably practical methods of vibration reduction have been applied and vibration remains unacceptably high, it may be necessary to reduce the exposure of workers to hand-arm vibration by job rotation or other management techniques. For example, in some countries the usage of chain saws has been limited to no more than two hours a day.

This approach has the disadvantage that although vibration exposure of some workers may be reduced, that of others may have to increase if total production is not to be adversely affected. Furthermore, careful planning and supervision of the activities of the workers concerned will be needed if effective control of vibration exposure is to be achieved by this means. This may increase costs.

NOTE. According to ENV 25349 halving of the exposure duration is equivalent to a reduction of 29 % in the 4 h energy equivalent acceleration.

Annex A (informative)
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Annex B (informative)
List of the most common machines and processes which expose people to hand-arm vibration

Employees using the tools listed below are exposed to the hazard and thus, potentially, at risk. However, the magnitude of the risks will depend on the vibration exposure of the persons concerned, i.e. the intensity of the vibration and the duration for which their hands are exposed to it. Exposure to hand-arm vibration may be expected to vary from person to person depending on the tasks performed and the tools used.

The list is not comprehensive. Regard any tool or machine which caused tingling or numbness in the user's fingers after about 5 min to 10 min operation as suspect.

B.1 Percussive metal-working

Powered percussive metal-working tools, including powered hammers for riveting, caulking, hammering, clinching and flanging; hammer swaging, needle guns (needle scalers).

B.2 Percussive tools used in stone-working, quarrying, construction industry, etc.

Percussive hammers, vibratory compactors, concrete breakers and drills used in mining, quarrying, demolition and road construction, etc.

B.3 Grinders and other rotary tools

Pedestal grinders, hand-held grinders, flex-driver grinders and polishers, rotary burring tools, sanders.

B.4 Timer and wood-machining tools

Chain saws, brush cutters (clearing saws), hand-held or hand-fed circular saws, barking machines, agricultural and gardening machines such as mowers, cultivators.

B.5 Other processes and tools

Pounding machines (rammers) used in foundry, concrete vibro-thickeners, and concrete levelling vibro-tables, impact wrenches, hammers.

B.6 Hand-guided machinery used in construction industry, agriculture, etc.

Annex C (informative)
Practical example on how to select vibration reduction measures: test of stopping a leak in an underground main

C.1 Analysis of the key elements

The task of stopping a leak in an underground water main has the following key elements:

FUNCTION

STOP THE LEAK

KEY ELEMENTS

LOCATE THE LEAK
BREAKOUT ROAD SURFACE
EXCAVATE SAND/EARTH FILL
ISOLATE DAMAGED SECTION OF MAIN
REPAIR LEAKING MAIN
BACKFILL EXCAVATION
REPAIR ROAD SURFACE

Each of the key elements could, of course, be sub-divided into sub-tasks and so on.

For example: REPAIR ROAD SURFACE comprises:

PREPARE MATERIAL
FILL HOLE
COMPACT AND LEVEL

C.2 Vibration reducing measures

The analysis of why water or gas mains leak may identify ways in which the incidence of leaks could, in the long term, be reduced by the replacement of old pipes and fittings.

The analysis may, for example, identify road construction and pipe installation practices as factors which contribute to the development of leaks (and to difficulties in repair or replacement) and show that it might be practicable to reduce these effects by improvements in both these areas.

Examination of the 'key elements' is likely to show that the traditional method used to locate leaks is very inaccurate and that several holes are excavated in the wrong place before the site of the leak is precisely located. Here modern electronic leak detection techniques could reduce considerably the exposure to vibration resulting from the use of 'traditional' methods.

The use of reduced vibration breakers to excavate access to the source of the leak would reduce the vibration exposure of persons carrying out this work but other ways of achieving this end could be considered.

Mounted or remote controlled breakers may be practicable in some cases. Mobile circular 'road' saws or high pressure water jets offer other possibilities.

Similarly when the repair has been completed and the excavation backfilled, alternative methods for restoring the surface hardness, texture and profile could be identified and evaluated in terms of all relevant task requirements.

On completion of the processes of analysis and evaluation, a revised process/procedure for the task of 'stopping leaks' should have been established which represents the best practicable means for the reduction of hand-arm vibration exposure previously with that task.

Annex D (informative)
Practical examples of vibration reduction measures by product design

D.1 It may be reasonably practicable to make use of adhesive or welded joints in a fabricated product as an alternative to riveted joints and so avoid the use of a pneumatic riveting hammer.

D.2 Architects could choose finishes for building surfaces which avoid the use of scabbling tools to produce a decorative effect.

D.3 Building designers could maximize the use of off-site prefabrication, which enables components of higher quality to be produced by mechanized methods, thus reducing on site 'cutting and patching' to fit, and makes positive allowances for manufacturing uncertainties by providing gaps and specifying mastic or other appropriate fillers.

D.4 The careful design of metal castings (including the selection of the most suitable material) can reduce the degree of hand finishing (fettling) required, improve product quality and/or permit the mechanization or automation of the process.

D.5 In case of existing products whose manufacture exposes employees to potentially hazardous values of hand-arm vibration, the product should be carefully examined with a view to re-designing them so as to achieve the above aims.

Annex E (informative)

Practical examples of vibration reduction measures by process design

E.1 Mobile road cutting machines and or trenching machines might be used for cable laying, water and main repairs and similar work instead of portable road breakers. The use of road drills in the demolition of some reinforced concrete structures can be much reduced, if not eliminated, by the use of hydraulic crushing or nibbling techniques. Large blocks can be fragmented by the use of hydraulic expanding devices inserted into pre-drilled holes.

The use of electronic detectors enabled one firm to locate leaks from buried pipelines more precisely and thereby reduce the usage of road breakers and increase productivity. The same firm achieved a further increase in productivity and a reduction in vibration exposure by adopting a 'no dig' strategy for the replacement of ageing, buried pipe systems.

Instead of the traditional approach of digging out, replacing and recovering, they adopted renovation techniques involving scraping out and relining in-situ.

E.2 The amount of fettling required by castings (and hence the vibration exposure of the fetters) is affected not only by the casting design and material but also by the method of manufacture selected and the skill with which it is carried out. The more precise the method and the higher the quality of the production process, the less the need for manual rectification and finishing.

For example, a company manufacturing castings of up to 350 t in a variety of steel alloys, who substituted a moulding process based on the use of cold setting phenolic resins for the traditional green sand method, found that it gave better casting quality (improved dimensional accuracy) and greatly reduced the amount (and cost) of fettling and rectification work.

When fettling castings, for example, it is often more economic as well as less hazardous to rough machine, rather than hand fettle, surfaces which are later to be finished by machining.

E.3 Often ways of improving the process will be found which not only reduce hazardous vibration (and possibly other hazards, e.g. noise) but also improve productivity.

In the ship building industry, chipping hammers and portable grinders were used to prepare the edges of plates, dress welds, and to remove the welded brackets and stiffeners (fairing aids) traditionally used to support and align parts of ship structures during assembly. Re-appraisal of the process led to a new approach which involved cutting out the plates accurately to ensure a better fit and using magnetic or vacuum clamps and hydraulic devices, to align them. By these and similar measures applied elsewhere in the process, the use of chipping hammers and portable grinders has been greatly reduced with the result that not only the vibration exposure of workers has been reduced but productivity has been considerably increased.

NOTE. This approach also resulted in reduced noise exposure.

The polishing of plated components on buffing, finishing and similar machines exposes the hands of workers to vibration, but the need for this work can sometimes be reduced by introducing preliminary, chemical, polishing processes.

Automation: in one firm, vibration exposure due to the hand grinding of precision components to improve balance was eliminated by automating the balancing process. This not only improved the working environment but also increased productivity.

In the foundry industry the use of manipulators and remote control swing grinders allows more power to be applied during fettling thereby improving productivity. The operator's hands are removed from direct contact with source of vibration (the grinder), and provided the hand-held controls are well isolated from the grinder, e.g. hydraulic remote controls or pendulum arm control incorporating vibration isolation, should be effectively protected from hazardous vibration.

Similarly, for some applications — such as the removal of runners and risers from castings, bar cutting, and the cutting of concrete blocks and slabs — manually operated cut-off saws can be replaced by enclosed, remote controlled or semi-automatic models. The advantages of this approach are not only the reduction or elimination of vibration exposure, but also reductions in noise and dust levels, and in the physical effort required to perform the work.

Robots are finding increasing application in industry and various industrial organizations have developed robot or highly automated grinders and burring machines for the removal of feeder heads and other fettling operations.

Annex F (informative)

Practical examples of vibration reduction by selection of machinery or equipment

In the case of pneumatic grinders, sanders and drills, research has shown that the variation between tools of the same type and rating can be considerable. Differences of more than 100 % can occur in the vibration values of chain saws, hammers, breakers, etc. of similar ratings.

Choose grinding wheels carefully. Research has shown that the combined effects of residual unbalance in the grinding wheel can be a major cause of high vibration values in portable grinders and that the initial unbalance persists throughout the life of the wheel. Reductions in handle vibration, in the order of 3 to 1 or more can, in many cases, be achieved by simply minimizing these effects. Many manufacturers can supply wheels to tolerances much lower than those currently specified in international standards. Users should therefore discuss this matter with their suppliers with a view to obtaining grinding wheels with low levels of unbalance and reducing dimensional tolerances. Under conditions of very heavy use, other sources may predominate and other factors, such as wheel dimensions, wheel composition and the operating characteristics of the grinder, may exert an influence.

When choosing powered screwdrivers, nut runners and torque wrench for assembly work, select, where reasonably practicable, simple rotary action rather than impact or impulse action tools. Although this will mean that special devices will be needed to resist the torque reaction forces, additional benefits, including reduction of A-weighted noise of over 20 dB, can be obtained.

Annex G (informative)

Short list of the most important questions that potential buyers should ask potential suppliers with regard to hand-arm vibration

When considering the purchase of new tools and equipment, buyers should ask suppliers for information about the vibration of the tools (or other equipment) they are thinking of buying. The following short list indicates some of the more important questions that should be asked.

- Is the vibration of any handle or other surface which must be held by the tool or equipment user likely to exceed an equivalent continuous frequency weighted acceleration of 2,5 m/s^2, in normal use?

If the answer to the above question is YES, what is the equivalent continuous frequency weighted acceleration:

- under operating conditions producing the highest vibration; or
- under typical operating conditions encompassing the range of work or operations for which the machine, tool or equipment is designed; or
- under other standard conditions?
- under what operating conditions were the measurements made?

If the tests were in accordance with a published standard, please provide details and indicate the extent to which the vibration may differ from the quoted values under normal conditions of use.

Further questions are:

- what measures have been taken to minimize vibration?
- are additional vibration reduction measures practicable? Please give details of any design changes, the additional cost and of any production penalties;
- what is the maximum equivalent continuous frequency weighted acceleration that the tool or equipment can be guaranteed not to exceed?
- what tests would be carried out to confirm any claims made in answer to the previous question?
- what other measures are required to minimize the vibration hazard, to which employees are exposed when using the tool or equipment in question?

Please give details of any special maintenance requirements.

Annex H (informative)

Practical maintenance measures that should be taken to reduce vibration exposure

H.1 Cutting tools should be regularly sharpened.

H.2 Grinding wheels should be regularly and correctly dressed by using a suitable procedure, recommended by the manufacturer, which ensures concentricity of the wheel and a correct profile. Properly dressed wheels not only reduce the vibration exposure of workers, but also provide increased metal removal rates and therefore lower production costs.

H.3 Worn parts should be replaced before the wear causes an excessive increase in vibration values.

H.4 Where necessary, balance checks and corrections should be carried out, e.g. the balance of grinders could be checked prior to issue from stores.

H.5 Anti-vibration mounts and suspended handles should be replaced before they have deteriorated to such an extent that the vibration exposure of workers is significantly increased. Deterioration of rubber mounts, in the form of cracking, swelling (such as is caused by oil contamination), softening and conversely hardening can sometimes be detected by visual examination and simple tests but generally the maker's advice should be sought.

H.6 Vibration dampers should be regularly checked and replaced if defective.

H.7 The conditions of bearings and gears should be regularly checked and replaced if defective.

H.8 In the case of chain saws, the saw teeth should be maintained in a sharp and even condition. Chain tension should be correct, since if it is not, the chain hammers on the guide bar and the overall vibration value is increased. Engines should be kept well tuned, with correct spark plug and carburettor settings being frequently checked.

List of references

See national foreword.

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ISBN 0 580 25152 7 GME/21