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Hand-arm vibration - Guidelines for vibration hazards reduction - Part 1: Engineering methods by design of machinery

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Hand-Arm-Schwingungen-Leitfaden zur Verringerung der Gefährdung durch Schwingungen - Teil 1: Technische Maßnahmen durch die Gestaltung von Maschinen

Vibrations main-bras - Guide pour la réduction des risques de vibrations - Partie 1: Mesures techniques lors de la conception des machines

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CEN

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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 transmits vibration to the hand may cause disorders of the upper limbs. The effects of vibration depend on its frequency, direction, intensity and magnitude, and on the exposure time and coupling of the hand-arm system to the machine. The effects also depend on the hand-arm position caused by the design of the grip and the working task. They are also affected by forces exerted by the operator such as gripping, pushing and pulling forces, and by the skill and practical experience of the operator. Exposure to cold may be relevant to the vascular symptoms caused by hand-transmitted vibration.

Limiting vibration by design, is one the measures which EN 292-2 suggests machine manufacturers and designers should consider as part of a strategy to achieve safety by design of machinery in conformity with European Legislation.

The reduction of vibration by design of machinery can make an important contribution to the effective protection of persons at work from the harmful effects of vibration. In practical situations however, a combination of measures may be necessary which can be categorised under the headings:

- engineering measures;
- management measures;
- personal protection;
- hygiene measures (law, directives, etc.).

These guidelines only deal with engineering methods and in particular with comments to designers and manufacturers of machinery which transmits vibration to the hand leaving to others, the task of defining specific guidelines on management, personal or hygiene protection (see CR 1030-2).

Engineering methods

Machinery vibration may be due to oscillating forces generated internally by the intermittent, impulsive or cyclic way in which machines are designed to work, by unbalance, and/or by impacts in gears, bearings and other mechanisms.

Vibration can also be caused by unbalance of an inserted tool. For example, unbalance of the grinding disc is one factor that determines the vibration values of a hand-held grinder.

Vibration can also be caused by the interaction between operator, machinery and material being worked: for example when the shocks or impulses of a pneumatic chisel, as it hits the surface being chiselled, are reflected into the body of the tool.

In the case of machinery, such as pedestal grinders and linishers, at which the workpiece is hand-held or hand-guided during working, the interaction between workpiece and machine is likely to be the chief source of vibration. The transmission through the workpiece is the principal route by which vibration reaches the operator's hands.

The above parameters should be taken into account by designers, manufacturers, and suppliers of equipment for use at work, who are obliged to ensure that their designs and products satisfy safety requirements; in particular, to design machinery so that the risks from vibration produced by the machinery are reduced to the lowest level, taking into account technical progress and the availability of means of reducing vibration, in particular at source (see annex A of EN 292-2).

To reduce the vibration stress for the user, it is essential to pay attention not only to the vibration magnitude but also to the coupling of the machine to the hand-arm system and to the exposure time. All three parameters can be influenced by technical measures (e. g. coupling can be influenced by an ergonomic design of machinery; the exposure time can be reduced by increasing the performance of the machine).

1 Scope

These guidelines outline feasible ways in which possible hand-arm vibration hazard associated with hand-held, hand-guided and other machinery, may be reduced by machinery design in order to provide practical professional aid to designers and manufacturers of machinery. The document covers four principal aspects of the reduction of the effects arising from exposure to hazardous machinery vibration:

- reduction of vibration magnitude at source;
- reduction of vibration transmission from the source to handles and other surfaces in contact with the hands;
- reduction of vibration transmission from the grips or handles of the machine to the hand-arm system of the operator by ergonomic design measures;
- thermal design to optimise hand temperature.

NOTE: These guidelines are not intended to be universal or detailed solutions but only technical methods which may be used to solve problems.

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.

EN 563 Safety of machinery – Temperature of touchable surfaces – Ergonomics data to establish temperature limit values for hot surfaces

prEN 894-3 Safety of machinery – Ergonomic requirements for the design of displays and control actuators – Part 3: Control actuators

3 Reduction of vibration magnitude at source

Machinery for which the emission of vibration is not necessary for fulfilling the working task, should be designed so as to eliminate or reduce the oscillating forces causing vibration, to prevent amplification of vibration, and to damp or reduce residual vibration. Care should be taken that by any such means the weight of hand-held machines is not significantly increased as this leads to other negative results. This means, for example, that higher weight of machinery leads to higher forces for grasping and carrying the machine which cause a higher intensity of vibration transmission and thus leads to a higher vibration load. In the same way, higher weight of machinery leads to higher physiological muscular load. Furthermore, the ease with which the machine can be controlled and guided should not be impaired (e. g. by using very soft, suspended handles).

3.1 Reduction of vibration by changing the technical principle of operation

In some cases a reduction of vibration, exposure time and operating forces may be realized by changing the technical principle of machine operation.

NOTE: A typical example is the case of small rotary hammer. It has a pneumatic hammer mechanism and drills into concrete much faster, produces lower vibration and requires lower feed and grip forces than an impact drill with a cam-action impact mechanism.

3.2 Reduction of vibration by better balance

One common source of oscillating forces is unbalance which may be due to:

- the operating principle utilised (e. g. the forces generated in reciprocating engines as a result of the crank and connecting rod motion);

- manufacturing tolerances and/or residual errors in the construction of rotating parts (e. g. eccentricity in the mounting of a wheel on a shaft and/or non-uniformity of form, composition or structure).

Where the forces are inherent in the design they can sometimes be reduced by the use of intrinsically better balanced designs (e. g. in the case of internal combustion engines by the use of multi-cylinder rather than single-cylinder designs or by the use of rotary rather than reciprocating engines).

Alternatively, it may be possible to minimise the oscillating forces by modifying the mass and/or speed or acceleration of the components generating the unbalance. The incorporation of counterbalancing masses (e. g. as in some polishing machines) may also be practicable.

NOTE: Care needs to be taken to ensure that a reduction in speed or acceleration does not reduce the machine performance to such an extent that the increase in exposure time would offset the reduction in vibration intensity.

Where the forces are the result of manufacturing tolerances or residual errors in construction (e. g. the tolerances on residual unbalance, form or mounting hole dimensions of grinding wheels), it may be practicable to reduce them by specifying tighter manufacturing tolerances, (i. e. higher product quality).

3.3 Reduction of vibration by introducing reactive forces

Where low frequency oscillatory working forces are utilised in hand-held machinery their effect on machinery users can sometimes be significantly reduced by contra-moving masses. The design could also incorporate a spring system to absorb the reflected shock waves produced by each impact.

3.4 Reduction of vibration due to oscillating forces by use of alternative mechanisms or materials

Many of the mechanisms used in machinery generate oscillating forces and hence vibration (e. g. inaccuracies in gears and bearings). These forces can often be eliminated or minimised by the use of alternative mechanisms (e. g. belt drives rather than gear or chain drives), by better versions of a particular mechanism (e. g. helical gears instead of plain cut gears) and the specification of high precision components (e. g. high quality components with minimum backlash).

In some applications it may be possible to reduce shock and impact forces by incorporating resilient elements of rubber, or wear resistant plastic, or similar materials (e. g. resin bonded gears).

3.5 Avoiding resonance effects

The various parts of machinery may exhibit resonance if the frequency or frequencies of oscillating forces generated when the machinery is used are close to the natural frequency of vibration of the machinery or various parts of it. In the absence of any means of absorbing vibration energy, considerable amplification of the vibration may result if resonance occurs.

Where practicable, designers should avoid resonance within the normal speed range of the machinery by a suitable choice and arrangement of resilient elements and masses, by appropriate selection of bearings, by careful selection of gear mesh frequencies and by other measures.

If resonance effects cannot be avoided, it may be necessary to incorporate viscoelastic, hydraulic, air, friction or some other form of damping to absorb vibration energy and thus limit the intensity of resonant vibration. Tuned or untuned vibration absorbers may also be used to reduce the resonance effect.

4 Reducing vibration transmission

4.1 General

The vibration may be reduced by the introduction of vibration isolation techniques (masses, springs and other resilient elements) into the paths from sources of vibration to handles and other surfaces in contact with the hands.

Considerable care is needed if effective isolation is to be achieved over the whole frequency range of interest. In some cases difficulty may be experienced in isolating low frequency vibration. The resonance frequency of a suspension should be lower than 0,7 times the lowest significant vibration frequency that occurs during operation.

4.2 Reduction of vibration by the use of suspended handles

To achieve substantial reduction in vibration by the use of suspended handles, the dynamic characteristics of the handles need to be matched to the vibration characteristics of the machinery to which they are fitted.

At present, good isolation may be obtained at frequencies above 100 Hz, but low frequency performance may be less good and vibration magnitudes may be higher on the suspended handle than on a rigidly mounted one (i. e. at some frequencies the suspended handle may amplify vibration).

The design of such handles is often a compromise since handles sufficiently well suspended to attenuate vibration at very low frequencies may make the machine to which they are attached difficult to use with precision. It may thus be necessary to increase the stiffness of a suspended handle beyond the ideal value, with the consequence of some reduction in its isolation efficiency.

Some of these problems may be overcome by increasing the mass of the handle and reducing that of the source. For example, the vibration to which users of chain saws are exposed has been considerably reduced on some machines, by integrating the handles with the fuel tank and using a resilient mounting system to isolate the combination from the motor and the saw blade.

NOTE: Suspended handles have been applied to some machines, including pneumatic sand rammers, hammer drills, angle grinders, rock drills, breakers and chain saws. These rely on the use of mass and resilient elements for their effect. In some cases, mounting the handles at points of low vibration has helped.

4.3 Use of resilient materials

New resilient materials may be worth considering as coverings for handles and other vibrating surfaces in contact with the hands. The form, dimensions (thickness), and conditions of use (preloading) need to be carefully chosen to meet appropriate dynamic requirements. Ergonomic constraints (handle size, etc.) may limit the application of this approach. Such materials are, in most practical situations, only likely to be efficient in frequency ranges above 200 Hz.