
Mehanske vibracije in udarci - Prenos vibracij na roke - Vpliv sklopnih sil pri vmesniku ročnega stroja na ocenjevanje izpostavljenosti

Mechanical vibration and shock - Hand-transmitted vibration - Influence of coupling forces at the hand-machine interface on exposure evaluation

Mechanische Schwingungen und Stöße - Hand-Arm-Schwingungen – Einfluss der Ankopplungskräfte an der Schnittstelle zwischen Hand und Maschine auf die Bewertung der Schwingungseinwirkung

Chocs et vibrations mécaniques - Vibrations transmises à la main - Evaluation de l'exposition aux effets des forces de couplage à l'interface entre la main et la machine

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Vpliv vibracij in udarcev na ljudi

Vibration and shock with respect to human beings

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Schwingungen - Einfluss der Ankopplungskräfte an der
Schnittstelle zwischen Hand und Maschine auf die
Bewertung der Schwingungseinwirkung

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EUROPEAN COMMITTEE FOR STANDARDIZATION
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EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: Avenue Marnix 17, B-1000 Brussels

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Foreword

This document (CEN/TR 16391:2012) has been prepared by Technical Committee CEN/TC 231 “Mechanical vibration and shock”, the secretariat of which is held by DIN.

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Introduction

The coupling force between the hand-arm system and a hand-held, hand-guided or hand-fed machine during its use is an important factor in the transfer of damaging vibration energy to the hand and arm. There is evidence that reducing coupling forces is likely to decrease the damaging effects of exposure to hand-transmitted vibration. However, the relationship between vibration exposure, coupling forces and damage to the hand-arm system is still the subject of research studies. There is a need for practical advice for users on how to minimise and control contact forces and guidance on how to account for those reduced contact forces when assessing vibration exposures. Machine manufacturers of hand-held and hand-guided machines need advice on how to achieve the best compromise between the requirements for both low coupling forces and low vibration magnitudes.

The aims of this Technical Report are to:

- provide guidance on good-practice for both workplace control of exposure and machine design and
- encourage further research to improve the current state of knowledge.

This Technical Report provides an overview of the current state of knowledge on the relationship between vibration exposures, coupling forces and damage to the hand-arm system. It provides general guidance on how to build the reduction of coupling forces into workplace action plans to control vibration exposures and how the reduction of coupling forces may be incorporated into machine design. An example of an empirical relationship for accounting the coupling force in assessments of vibration magnitudes is also provided.

Technical Reports have no effect on the regulations specified by European Directives. That means that at present coupling forces should not be used to modify workplace assessments of vibration exposure according to the EU Physical Agents Directive (vibration) 2002/44/EC or the measurement of vibration emission declared according to the EU Machinery Directive 2006/42/EC.

1 Scope

This Technical Report provides an overview of the current state of knowledge on the relationship between vibration exposures, coupling forces and damage to the hand-arm system. It provides general guidance on how to build the reduction of coupling forces into workplace action plans to control vibration exposures and how the reduction of coupling forces may be incorporated into machine design. An example of an empirical relationship that accounts for the coupling force in assessments of vibration magnitudes is also provided.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1005-2, *Safety of machinery — Human physical performance — Part 2: Manual handling of machinery and component parts of machinery*

EN 1005-3, *Safety of machinery — Human physical performance — Part 3: Recommended force limits for machinery operation*

EN ISO 5349-1, *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 1: General requirements (ISO 5349-1)*

EN ISO 5349-2, *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 2: Practical guidance for measurement at the workplace (ISO 5349-2)*

ISO 15230:2007, *Mechanical vibration and shock — Coupling forces at the man-machine interface for hand-transmitted vibration*

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3 Symbols and abbreviations

For the purposes of this document, the symbols and abbreviations given in ISO 15230:2007 apply.

4 Contact force and hand-transmitted vibration

EN ISO 5349-1 recognises that, although characterisation of the vibration exposure currently uses the acceleration of the surface in contact with the hand as the primary quantity, it is reasonable to assume that the biological effects depend largely on the coupling of the hand to the vibration source. It further notes that the coupling of the hand to the vibrating surface can affect considerably the vibration magnitudes measured.

The importance of coupling force on measurement is also emphasised in EN ISO 5349-2, which advises that different measurement ought to be made if there are changes in the feed forces applied to machines.

EN ISO 5349-1 states that coupling forces should be measured, and notes that a standard on measurement of coupling forces was (in 2001) in preparation. ISO 15230 was published in 2007 and defines parameters relating to the measurement of coupling forces (feed-force, grip force, contact pressures, etc.).

ISO 15230 defines the coupling force as the combination of compressive push/pull and grip forces. It provides a basis for obtaining good-quality information on the forces between the vibrating surface and the hand. However, workplace measurement of coupling force is a complex process that requires specialised equipment and knowledge.

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NOTE Coupling force does not include forces acting tangentially to the vibrating surface, such as the force required to twist a handle. It is the (compressive) coupling force that is assumed to influence the transmission of damaging vibration energy into the hand.

5 Influence of coupling force on vibration exposure evaluation

The method for assessing workplace exposure to hand-arm vibration is standardised in EN ISO 5349-1. This standard evaluates the risk of harm from vibration based on two factors:

- the vibration at the surface in contact with the hand and
- the exposure time over the working day.

However, EN ISO 5349-1 also recognises that the biological effects of vibration are likely to depend on the coupling of the hand to the vibration source.

Annex A summarises the state of current knowledge on the relationship between vibration exposure, coupling force and damage to the hand-arm system. The relationship between vibration exposure, coupling forces and damage to the hand-arm system is still the subject of research studies. However, there is evidence that reducing coupling forces is likely to decrease the damaging effects of exposure to hand-transmitted vibration.

Methods for compensating data on vibration magnitude according to the coupling force have been developed. Annex B provides an example of one such system. The method shown in Annex B requires information on coupling forces, based on measurements according to ISO 15230. Currently there is limited data available on typical coupling forces for normal workplace tasks. Annex C shows some examples of the coupling forces used for a range of hand-held and hand-guided machines.

This Technical Report provides a bibliography of papers that contribute to the evidence linking coupling forces associated with the use of hand-held and hand-guided machinery and vibration injury.

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6 Control of coupling forces in the workplace**6.1 General**

In general, workplaces and work tasks should be designed as far as possible to provide workers with ergonomically good postures for both the body and the hand and arm. Awkward and strained postures will tend to result in higher than necessary coupling-forces between the hand and the handle of the machine.

The work tasks should be generally designed to promote minimum coupling forces. This should begin with selection of the most appropriate machines for the task; it may also include adapting the workstations to reduce contact forces and will include the provision of information for and instruction and training of the machine operators.

Some actions to reduce coupling forces may increase the magnitude vibration, when evaluated according to EN ISO 5349-1. Understanding how and why the vibration increases may help to identify solutions that will lead to both reduced coupling force and reduced vibration exposure.

6.2 Machine selection

Hand-held machines (power tools) should be selected based on their capability to do the job. In general, smaller, more compact, machines tend to require lower supporting and twisting forces to hold and manoeuvre them and should be used where they are an option. However, smaller, low-weight, machines may not be suitable if they need higher feed and gripping forces to compensate for the reduced mass. Sometimes, larger and heavier machines are simply more capable of doing the job being asked of them. For this reason, good ergonomic design of machines may be more important than simply reducing the mass and making the machine smaller.

Things to consider when selecting machines for the workplace:

- a) Is it able to the job?
- b) Does it perform the task efficiently?
- c) Is it designed ergonomically such that it:
 - 1) is easy to operate,
 - 2) is comfortable to use and
 - 3) requires low coupling forces?
- d) Is it low-vibration?

6.3 Workstations and work-tasks

Guidance on ergonomic design criteria and assessment of manual-handling risks related to work activities is given in EN 1005-2. While EN 1005-2 specifically excludes hand-guided (including hand-held) machines, the general good ergonomic practices may be employed, such as:

- Bringing work pieces up to the natural working level of the worker;
- Orienting work pieces so that the worker is not required to lift and apply force away from the body;
- Providing overhead-support for hand-operated machines.

Additional guidance is given in EN 1005-3 on the applied forces that can be applied by typical working populations under different work situations.

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Overhead support for machines can provide an opportunity for introducing vibration controls that would not normally be possible because of the additional weight. Effective vibration reductions have been achieved by fitting the hand-held machine into a frame with vibration-isolated handles. With the weight of the machine supported, the worker is only guiding the machine and the additional weight of the frame does not add to the load that the worker has to support.

Adding mass can have an additional advantage; it will act to reduce the amount of motion in the body of the machine, reducing the vibration magnitude.

6.4 Information and training

Users of machines need to understand how to get the best out of the machines they use. It is important that workers understand how a machine needs to be operated, why certain operating methods are recommended and why others are not desirable.

Instruction and training provided to users should be based on information provided by machine manufacturers on the safe use of their machinery.

When excessively high push forces are applied the magnitude of hand-arm vibration on machines often increases. This increase in vibration is not usually indicating more effective machine operation and may be an indicator that the machine is no longer operating efficiently. Unfortunately, the machine operator can misinterpret this increase in vibration (and noise) as an indication that the machine is working more effectively and will apply forces much higher than those that are necessary for the task being performed.

CEN/TR 16391:2012 (E)

Many machines are designed with anti-vibration systems that isolate the worker from the vibration of the machine. Poorly trained operators often relate low vibration with low work-rates of the machine, and push harder until they can feel the vibration. This overloads the anti-vibration systems, giving the worker a high vibration exposure but makes little difference to the real work rate.

It is generally important that the workers allow the machine to do the job and that they do not put in excessive effort themselves. The feeling that there is a need to push hard can be a result of the machine accessories being inappropriate for the job, or poorly maintained. Examples of conditions that lead to excessive force being applied include:

- a) Blunt drill bits, moil-points or chisels – Workers feel the need to push if the machine is not operating as quickly as it normally does. This may be due to blunt accessories. In addition, excessive push forces will cause drill bits and chisel to become blunt more quickly than they should.
- b) The wrong accessory for the job – Using an abrasive that is too hard for the task can result in the abrasive surface becoming smooth rather than wearing properly. Abrasives that are too soft will quickly wear, without being able to adequately abrade the surface. In both situations, the worker will feel that it is necessary to push harder to get the work done.
- c) Poorly maintained machines – For most machines with a rotary action, any out-of-balance in the machine can both increase vibration and increase the forces required to properly control the machine.

Reduced machine performance is one indicator that a machine is in need of maintenance or inspection. Workers need to be trained to recognise the changes in machine characteristics that indicate the need for inspection and maintenance. These signs may include:

- more time required to do the job,
- greater forces required (increased strain and coupling forces),
- increase vibration,
- increase noise,
- overheating.

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7 Design of machinery

7.1 General

Machines designed using the guidance and recommendation provided in EN 1005-2 and EN 1005-3 will improve general ergonomic handling of machines, and lead to optimised coupling forces between the hand and machine handles.

EN 1005-2 provides ergonomic recommendations for the design of machinery involving manual handling. While EN 1005-2 specifically excludes hand-guided (including hand-held) machines, the general good ergonomic practices are applicable to all hand-machines. This standard gives guidance on factors such as mass, mass-distribution, size, grips and handles and working postures.

EN 1005-3 provides guidance to the manufacturers of machinery on controlling health risks due to machine-related muscular force exertion. It provides recommended force limits for machinery, based on the actions being carried out and the capability of the working population to provide the necessary force. It considers speed, frequency and duration of the operation that will be carried out with the machine.

7.2 Applied force and machine efficiency

Machines should be designed such that the coupling forces required for the most efficient operation of the machine are considered when designing the machine for good ergonomic handling.

7.3 Indicators for operators on applied force

Machines can be designed to make it clear to the user when excessive push forces are being applied, for example:

- Road breakers with suspended handles or bodies indicate the correct applied force by being in the centre of their suspension range;
- Some large electric drills are designed to stall if excessive feed forces are applied.

7.4 Handle characteristics

Machine handles should be designed to encourage the machine with minimum required operating forces. Triggers should be designed and positioned so that minimal force is required while the machine is operating (consistent with other safety considerations) and should not encourage operation of the machine when it is not normally required (e.g. when pulling a road-breaker out of a hole).

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