TECHNICAL REPORT

ISO/TR 25398

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Earth-moving machinery — Guidelines for assessment of exposure to whole-body vibration of ride-on machines — Use of harmonized data measured by international institutes, organizations and manufacturers

Engins de terrassement — Lignes directrices pour l'évaluation de l'exposition des vibrations à l'ensemble du corps sur les machines à conducteur porté — Utilisation des données harmonisées mesurées par des instituts internationaux, des organisations et des fabricants

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 25398 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*, Subcommittee SC 2, *Safety requirements and human factors*.

Introduction

This Technical Report provides information on how to assess the whole-body vibration exposure of operators of earth-moving machines. The method is based on measured vibration emission under real working conditions. It needs to be noted that vibration emissions are influenced by many different parameters, originating from

— operator (e.g. training, behaviour, mode, stress),

— jobsite (e.g. organization, preparation, environment, weather, material), and

— machine (e.g. type, quality of seat and suspension system, attachment, equipment, condition).

It is therefore not possible to obtain precise exposure figures. The values given in this Technical Report need to be used with great care since they were measured for a limited number of operators, defined work situations, and machine types.

On the one hand, the actual work situation for a specific machine operator can be very different, thus creating different vibration. On the other hand, values from real work that can be found in the literature are only correct for the specific work situation and time when they were measured. The user of this Technical Report needs to be aware that the exposure to vibration depends not only on the machine used but also to a large extent on the operator, jobsite and machine, and other factors. All these factors need to be taken into account in order to make a practical assessment of vibration magnitude.

There are typical operating conditions for machine types in accordance to ISO 6165 identified and listed in Annex A. This list may not be complete, but it represents most of the real working conditions.

Properly adjusting and maintaining machines, operating machines smoothly, and maintaining the terrain conditions can reduce whole-body vibrations. The guidelines given in Annex E can help users of earth-moving machines reduce the whole-body vibration levels.

The daily vibration exposure to be assessed depends on both the magnitude of vibration at the surface in contact with the whole body and the total daily duration for which an employee is in contact with that vibration.

The vibration levels for the same type of machine are assumed to be the same. If a vibration-reduction feature is added to the machine, then a lower vibration level can be used. In order to determine the reduction in vibration levels for a machine vibration-reduction feature, the appropriate vibration measurements must be made. Annex F provides guidelines for vibration measurements.

Earth-moving machinery — Guidelines for assessment of exposure to whole-body vibration of ride-on machines — Use of harmonized data measured by international institutes, organizations and manufacturers

1 Scope

This Technical Report provides guidelines for those such as employers, national authorities and manufacturers of earth-moving machinery who are required to determine, assess and document the daily whole-body vibration exposure for ride-on machines as defined in ISO 6165. It also provides guidelines for reducing vibration levels on machines and for determining the vibration reduction from machine improvements to reduce vibration levels. It is intended to assist in establishing documentation for specific earth-moving machinery under typical operating conditions.

It gives guidance on determining the daily vibration exposure A(8), in accordance with ISO 2631 and EN 14253, offering a simple method for determining the daily vibration exposure by means of a table which indicates the daily exposure as a function of the equivalent vibration total value and the associated exposure duration. Both methods can be used even in cases of multiple exposures on the same day.

Methods are provided for calculating exposure using reported emission values, valid for machines equipped with a seat in accordance to ISO 7096.

NOTE Additional information is given in the EN 474 and EN 500 series of standards.

Workplace measurements are required where suitable data are unavailable to represent the vibration under the specific working conditions, or if the calculation results are not useful for determining whether or not the vibration exposure limit value or exposure action value is likely to be exceeded.

It is important that the vibration values used in the exposure assessment are representative of those in the specific use of the machines.

This Technical Report does not deal with assessments of exposure to shock.

NOTE The guidelines for determining, assessing and documenting the daily vibration exposure from use of ride-on operated earth-moving machinery also cover the requirements of the European Physical Agents Directive (Vibration) 2002/44/EC.

2 Normative references

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

ISO 2631-1:1997, *Mechanical vibration and shock — Evaluation of human exposure to whole-body vibration — Part 1: General requirements*

ISO 6165: 2001, *Earth-moving machinery — Basic types — Vocabulary*

ISO 7096:2000, *Earth-moving machinery —- Laboratory evaluation of operator seat vibration*

EN 14253:2003, *Mechanical vibration — Measurement and calculation of occupational exposure to whole-body vibration with reference to health — Practical guidance*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2631 and ISO 6165 and the following apply.

3.1
operating time
ride-on time
daily duration of the operating time on the earth-moving machinery

NOTE It includes the interruptions required by the operating conditions and the break periods directly related to use.

3.2
exposure duration
T
total duration during which the whole body is in direct contact with the vibrating surface (seat) and exposed to relevant vibration

NOTE It is often confused with the operating time when determining the daily exposure duration, T. For example, the operating time on a wheel loader in a quarry is estimated by the operator at 7,5 h per day. However, the exposure duration is 5 h loading dumper (e.g. waiting for dumpers) and 1 h mining application (e.g. waiting for detonation), which yields T = 6,0 h.

3.3
equivalent vibration value
$a_{\text{w,eq}}$
maximum of the time-averaged totals of the vibration values of the various machines and their typical operating conditions, $a_{\text{w}i\text{,x,y,z}}$, during their associated exposure durations, T_i

NOTE 1 It is the maximum of $a_{\text{w,eqx}}$, $a_{\text{w,eqy}}$ or $a_{\text{w,eqz}}$, calculated using Equation (1):

$$a_{\text{w,eqx}} = \sqrt{\frac{1}{T}\sum_{i=1}^{n}(a_{\text{wx}i})^2 \cdot T_i}$$

$$a_{\text{w,eqy}} = \sqrt{\frac{1}{T}\sum_{i=1}^{n}(a_{\text{wy}i})^2 \cdot T_i} \qquad (1)$$

$$a_{\text{w,eqz}} = \sqrt{\frac{1}{T}\sum_{i=1}^{n}(a_{\text{wz}i})^2 \cdot T_i}$$

where n is the number of partial equivalent vibration values considered.

NOTE 2 Vibration values for the x and y directions are multiplied by a factor of 1,4, and this is included in the data in Annex B. If data are used from another source, care needs to be taken to ensure that the factor is included there also.

3.4
daily vibration exposure
A(8)
value on which assessment of the level of exposure to vibration is based, expressed as the equivalent continuous acceleration over an 8 h period and calculated as the highest (rms) value of the frequency-weighted accelerations determined on the three orthogonal axes (1,4a_{wx}, 1,4a_{wy} and a_{wz} for a seated operator)

NOTE 1 For the determination of A(8), see Clauses 5, 6 and 7, Annex A and Annex B, and ISO 2631-1.

NOTE 2 It is the maximum of the $A(8)_{x,y,z}$ values, calculated using Equation (2):

$$A(8)_x = \sqrt{\frac{1}{8\,\text{h}} \sum_{i=1}^{n} (a_{wxi})^2 \cdot T_i}$$

$$A(8)_y = \sqrt{\frac{1}{8\,\text{h}} \sum_{i=1}^{n} (a_{wyi})^2 \cdot T_i} \qquad (2)$$

$$A(8)_z = \sqrt{\frac{1}{8\,\text{h}} \sum_{i=1}^{n} (a_{wzi})^2 \cdot T_i}$$

where n is the number of partial equivalent vibration values considered, $a_{w,x,y,z,i}$ is the equivalent vibration value and T_i is the associated exposure duration.

NOTE 3 Vibration values for the x and y directions are multiplied by a factor of 1,4, and this is included in the data in Annex B. If data are used from another source, care needs to be taken to ensure that the factor is included there also.

3.5
partial vibration exposure points
$P_{Ei\,x,y,z}$
index describing the vibration exposure from a single machine and operating condition during the associated exposure duration in the x,y and z directions

NOTE 1 It is calculated for the corresponding direction using Equation (3):

$$P_{Ei\,x} = \left(\frac{a_{wxi}}{0{,}5\,\text{m/s}^2}\right)^2 \cdot \frac{T_i}{8\ \text{h}} \cdot 100$$

$$P_{Ei\,y} = \left(\frac{a_{wyi}}{0{,}5\,\text{m/s}^2}\right)^2 \cdot \frac{T_i}{8\ \text{h}} \cdot 100 \qquad (3)$$

$$P_{Ei\,z} = \left(\frac{a_{wzi}}{0{,}5\ \text{m/s}^2}\right)^2 \cdot \frac{T_i}{8\ \text{h}} \cdot 100$$

where $a_{w,x,y,z,i}$ is the equivalent vibration value and T_i is the associated exposure duration.

NOTE 2 Equation (3) sets a value of 100 points for a vibration exposure of 0,5 m/s^{2}A(8). Another vibration exposure value A(8) can be set to 100 points by substituting it for 0,5m/s^2 in the equation.

NOTE 3 Vibration values for the x and y directions are multiplied by a factor of 1,4, and this is included in the data in Annex B. If data are used from another source, care needs to be taken to ensure that the factor is included there also.

3.6
total vibration exposure points
P_{Etot}
maximum of the totals of the partial vibration exposure points $P_{\text{E}i\text{x,y,z}}$ within one day

NOTE 1 It is the maximum of $P_{\text{E,totx}}$, $P_{\text{E,toty}}$ or $P_{\text{E,totz}}$, calculated using Equation (4):

$$P_{\text{E totx}} = \sum_{i=1}^{n} P_{\text{E}\,i\text{x}}$$

$$P_{\text{E toty}} = \sum_{i=1}^{n} P_{\text{E}\,i\text{y}} \qquad (4)$$

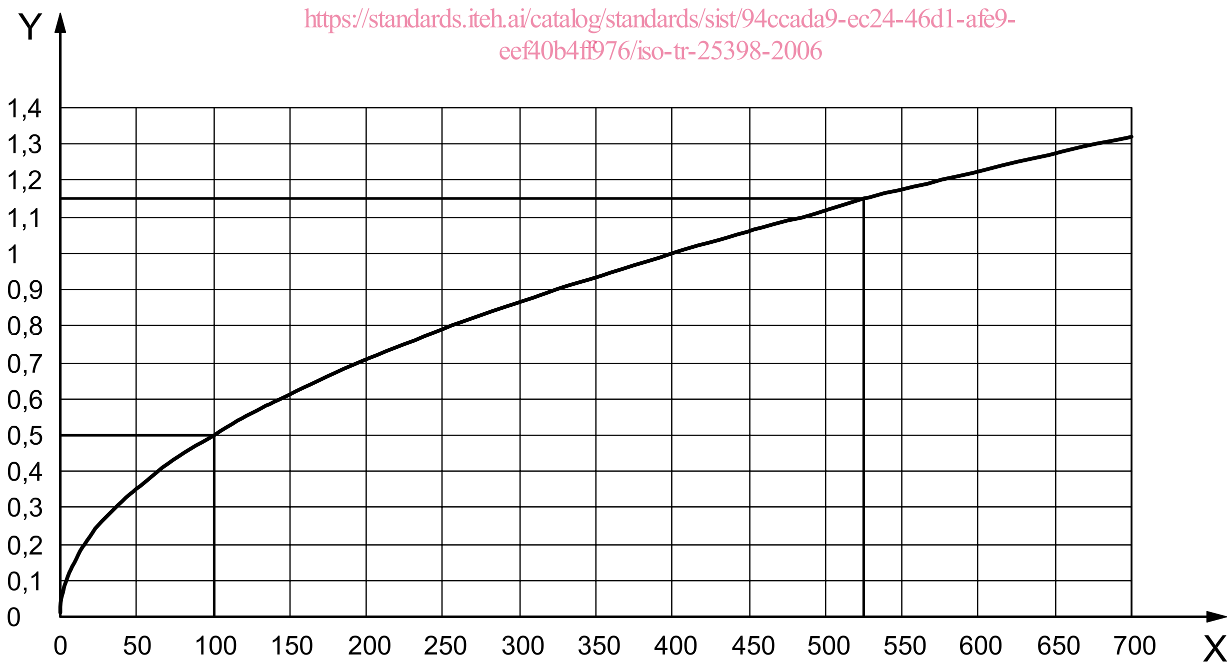
$$P_{\text{E totz}} = \sum_{i=1}^{n} P_{\text{E}\,i\text{z}}$$

where n is the number of partial equivalent vibration values considered.

NOTE 2 Vibration exposure points are a simple alternative to determining the A(8) value of an operator's total daily or partial vibration exposure. An example of the relationship is given by Equation (5), in accordance with the European Physical Agents Directive (vibration) 2002/44/EC:

$$\text{A}(8) = 0{,}5\,\text{m/s}^2\,\sqrt{P_{\text{Etot}}/100} \qquad (5)$$

A score of 100 points for the total vibration exposure in a day is equal to the exposure action value of A(8) = 0,5 m/s^2 and a score of 529 points is equal to the exposure limit value of A(8) = 1,15 m/s^2. The example is plotted in Figure 1.



Key
X total vibration exposure points, P_{Etot}
Y daily vibration exposure A(8), m/s^2

Figure 1 — Example of relationship between vibration exposure points and daily vibration exposure for whole-body vibration

4 Estimation of vibration magnitude

4.1 General

Data for estimating vibration levels are provided in Annex B. The vibration magnitude is expressed as a frequency-weighted root-mean-square acceleration value in metres per second squared (m/s^2), in accordance with ISO 2631.

The vibration magnitude for a machine can be highly variable. For example, an operator and his driving style (e.g. aggressive, smooth), different operating conditions, ground conditions, machine speeds or different materials all influence the actual magnitude. The magnitude also often varies over time. It is usually difficult or even impossible to obtain a precise value or narrow value range. The average value and a description of its uncertainty is the best reflection of the real, typical operating conditions. When estimating exposure, account should be taken of the fact that values are obtained within a range of uncertainty (see Clause 6).

4.2 Additional sources of information

Vibration magnitudes may be measured at the operator's position by the employer, or on his behalf. However, this can be difficult, non-reproducible and uneconomical, and is not always necessary.

Other sources of vibration data include specialist vibration consultants, employers' organisations (trade associations) and government bodies. Data can also be found in various technical or scientific publications and on the Internet. If an employer uses data from one of these sources, the quality and accuracy of the data should be checked. Comparing data from two or more sources is thus recommended. Employers should try to find a value (or range of values), which represents the likely vibration magnitude for the particular machine and operating conditions.

5 Estimation of daily exposure duration

The employer should determine the daily exposure duration for each operator and the relevant machines and operating conditions.

This may be based on

a) measurement of the actual exposure durations of a small number of operations or work cycles and calculating the average, and

b) information on the number of operations or work cycles per working day.

The first of these will be a measurement to determine how long an operator is exposed to vibration, and from what source, during a specified period. Various techniques may be used, for example:

- use of a stopwatch;
- analysis of video recordings;
- activity sampling.

A source of information may be work records, e.g. the number of lorries loaded and unloaded by fork-lift trucks.

However, it is important to ensure that the information is compatible with the information required for an evaluation of daily vibration exposure. For example, work records might give very accurate information on the number of completed work items at the end of each day, but where there is more than one operator, or unfinished work items at the end of a shift, this information might not be directly applicable to a vibration exposure evaluation.

NOTE Operators asked for information on their typical daily vibration exposure duration will normally give an estimate which includes periods of time when there is no vibration (e.g. idling, lifting for a fork-lift truck). Therefore, such an approach often results in an overestimation of the exposure duration.

It should be recognised that for most machines the vibration exposure duration is shorter than the operating time.

6 Consideration of uncertainties

The accuracy of the overall assessment of the exposure depends on the accuracy of the established vibration value and its ability to represent the actual vibration value. It also depends on the accuracy of the exposure duration as estimated. The datasets given in Annex B are based on from at least five and to more than 100 measurements under typical operating conditions. The standard deviation gives information about the distribution of the measured values.

The uncertainty in the estimation of exposure duration is affected by the uncertainty of

— measurements of the duration of operations or work cycles,

— estimates of the number of operations or work cycles per day,

— exposure time estimates supplied by the operators (see Note to Clause 5), and

— variability of the working task from one day to another.

The uncertainty in the evaluation of daily vibration exposure is affected by the uncertainty of

— evaluation of vibration magnitude, and

— evaluation of exposure duration.

NOTE Additional information about uncertainties of the measured vibration emission value is given in EN 14253.

The accuracy of the vibration value has more influence on the accuracy of the daily vibration exposure than that of the exposure duration because the vibration exposure is proportional to the vibration value and to the square root of the exposure duration.

The average values given in Annex B are likely to be exceeded in about half of all conditions. When making an initial estimate of exposure or where it is suspected that the conditions for a machine operation are particularly severe, it is recommended that the values used be the mean plus one standard deviation. There will be cases when even the value of the mean plus one standard deviation is exceeded. This is likely to occur in the 17 % most severe cases, i.e. the value (mean plus one standard deviation) will cover 83 % of all conditions. Machine vibration values will be less than the average values given in Annex B in about half of all conditions.

Conditions likely to lead to variability in levels of whole-body vibration include roughness or smoothness of terrain, driving speeds (adequate or inadequate), and adequate or inadequate operator skill and training.

Vibration levels can be reduced by following the guidelines given in Annex E.

