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PROTOCOL FOR WHOLE-BODY VIBRATION (WBV) MEASUREMENTS

1. Measuring equipment

Vibration are measured by using an equipment able to provide the effective value (r.m.s. value) of the acceleration of the surface that comes in contact with the user's body. Equipment -shall be compliant to the Standard ISO 8041.
Therefore, the equipment must be made, besides the accelerometers, by:

a) <u>a spectrum analyser (minimum three channels) without the recording chain</u>. This method presents the advantage of an immediate reading of the acquired spectra, but does not allow the subsequent processing of the signals acquired by analysis modes that are different from those used in the acquisition phase;

or:

b) <u>a measurement signal recorder (minimum three channels)</u>. The signal is then analysed by a spectrum analyser. The recorder shall necessarily be equipped with a overload gauge, in order to prevent distortions in the recorded signal.

Therefore, for the purposes of quality control of measurement, the spectral analysis of measurements, in thirds of octave, is required,

2. Specifications for the measurement

The specifications of the accelerometer commonly used for whole-body vibration measurements and of its adapter are reported in the Standard ISO 10326-1.

The measurements shall be compliant with the Standard ISO 2631-1.
In the case of measurements carried out at the driving position, the signal on the vehicle floor shall be acquired in addition and simultaneously to that measured on the seat, at least along the Z axis, in order to verify the presence of any peaks due not to the vibration transmitted by the vehicle but to movements of the operator on the seat. This condition is confirmed by the presence, in the signal detected on the seat, of peaks that are absent in the signal detected on the vehicle floor in the same measurement time series. The signal associated with the duration of such events may need to be excluded from the determination of the r.m.s. values of acceleration detected on the seat along the three axes of measurement. The signal on the vehicle floor can be acquired by rigidly fastening on the floor, in the immediate proximity of the seat, preferably on the metallic structure at the base of the seat, an uniaxial or triaxial accelerometer displaying features similar to those of the accelerometer mounted on the seat.
For the measurements in the upright position, the value on the vehicle floor shall be measured; if there is a shock absorbing structure on which the worker stands, it is necessary to measure the vibration both on this structure and on the vehicle floor itself.

3. Duration of measurement

The total measurement time, i.e. the number of acquired samples multiplied by the duration of the acquisition of each sample, should last at least three to four minutes. The measurements should be of such duration as to be able to **significantly** characterize the vibration transmitted to the worker's whole-body in the typical operating conditions in which the work is carried out (quality of the ground, forward speed, working task, load characteristics, etc.). In the event that the operating conditions vary significantly, **different tracks in different operating modes** shall be characterized in terms of r.m.s. frequency-weighted acceleration.
In order to check the quality of the data measured on the seat and to exclude interfering events, it is necessary to record the time history of the signal that has been simultaneously detected on the cushion and on the vehicle floor, with a sampling frequency of at least 1 sample per second. The curve of these signals should be attached to the measurement report.

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4. Assessment of uncertainty

The uncertainty factors that follow shall be assessed; the person responsible for the measurement shall determine, in each specific case, the main sources of uncertainty, and, in accordance to that, increase the number of acceleration measurements in order to quantify, by calculating the standard deviation, the extent of the error associated with the main indetermination factors.

The measuring equipment and the related calibrator must undergo calibration at an accredited calibration laboratory (national or EA center) at least every two years.

a. Biases due to the acquisition system (weight, location and mounting of accelerometers, electrical interferences, calibration). These measurement errors can be minimized by selecting an appropriate measurement technique. In this case the measurement error associated with this component is < 4 %.
b. Errors due to random fluctuations of the concerned physical parameters (temperature, humidity, stability of the machine power supply, homogeneity of the ground where the machine went to, etc.). These errors can be minimized by increasing statistics of the samples. The estimate of the random measurement error is obtained by the standard deviation of at least three measurements performed under identical experimental conditions.
c. Changes in the ways of driving of different operators and in the different anthropometric characteristics that affect the level of vibration detected on the seat: this factor shall be taken into account for the purposes of the inclusion of the data in VBD as the exposure is assessed for **homogeneous working tasks** and not for the individual worker. In this case the measurements shall be repeated in the same operating conditions, with at least two operators displaying different anthropometric characteristics and/or professional experience.
d. Changes in the maintenance and adjustment conditions of the machine (e.g., conditions of the shock absorbers, seat adjustment etc.): the measurements shall be carried out on machines that have undamaged seats, that regularly undergo maintenance and that are correctly adjusted for the weight of the driver.
e. Changes in the characteristics of the quality of the ground on which the vehicle is used (asphalt, mixed ground, presence of potholes or rocks etc.). These characteristics shall be specified in the data collection form.

5. Results of measurements

The results will be expressed in terms of mean value, standard deviation and coefficient of variation of the repeated measurements, calculated as follows:

$$C_v = \frac{S_{n-1}}{\overline{x}}$$ Coefficient of Variation

$$S_{n-1} = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1}^{n} \left(x_i - \overline{x}\right)^2}$$ Standard Deviation

$$\overline{x} = \frac{1}{n} \sum_{i=1}^{n} x_i$$ Mean Value

6. Quality Control

The laboratory must participate in intercalibration programs (Round Robin Test), by performing specific tests defined by the scientific referents.

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TECHNICAL FORM FOR WHOLE-BODY VIBRATION MEASUREMENT COLLECTION

Test report form for whole-body transmitted vibrations

Personal details (*)

Test performed by: ____________________________ Report responsible person:____________________________

Date:____ I declare to be authorized to publish the following
Place: ____ proposed data ☐

Working sector: ____

Examined vehicle (technical specifications)

Type:____(*) Manufacturer: ___________________________________(*)
Model:_______________________________________(*) Serial number/license plate: _________________________
Ballast (if present), kg: ____

Examined vehicle (functional specifications)

Maintenance condition of the vehicle (*):
☐ good ☐ mediocre ☐ poor

Vehicle cab (*)
☐present ☐ absent

Dampened axle: ☐ YES ☐ NO
Kind of suspension of the cab (if present):_____________

Tires
Type (*): ☐ full ☐ pneumatic
Brand: ____
Model: Front____________ Back__________ _
Inflation pressure (if pneumatic) (bar):
Front__________ Back ____________

Tracks (*): ☐ metal ☐ rubber ☐ absent

Any type of accessory (example: plough, mist blower, bucket, trailer, etc)

Type: ____(*) Description:_______________________________ (*)
Weight, kg: _______________________________________ Manufacturer: ______________________________

Conditions of use Attach photos of the machinery under the conditions of use and send a copy in digital format

Work cycle: ____________________________________(*) Description: __________________________________
Handled material (sand, aggregate, earth, nothing, other) (*):
Quality of the ground/road (*): ☐asphalt ☐ paved road ☐ cement ☐ packed dirt ground ☐ worked ground
☐ rails ☐ asphalt+paved road ☐ asphalt+packed dirt ground
Ground/road conditions (*): ☐ good conditions ☐ presence of potholes ☐ presence of obstacles (rails, crossings etc. .)
☐ uneven ☐ very stony ☐ slightly stony
Forward speed: ☐ slow ☐ moderate ☐ fast

Seat

Type of seat: ☐ standard ☐ optional Brand: ____
Seat classification: ☐ IT 1 ☐ IT 2 ☐ IT 3 ☐ IT 4 ☐ n.a. Model: ____
Characteristics of the suspension: ☐ pneumatic ☐mechanical ☐ none
Adjustments available on the seat: ☐ weight ☐ height ☐ weight/height ☐ none
Armrests: ☐ Present ☐ Absent

Measuring equipment - Attach photo of the accelerometer mounting on seat and floor (*)

Accelerometer - manufacturer, type, weight: ____
Preamplifier (optional) - manufacturer, type: ____
Analyser - manufacturer, type: ____
Recorder (optional) - manufacturer, type: ____

Data related to the calibration of the instruments issued by the EA center (or
equivalent):____

Mounting of transducer and of mechanical filter (*)

ATTACH PHOTOS OF THE MOUNTING

Notes:

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Results: Results can be expressed as values in octave band or as weighted values.

Weighted and linear effective values – A operator (weight kg____height cm_____): a(x,y,z) values in m/s^2 r.m.s.

	Test										**Measurement conditions and measurement duration**
	Linear seat				Vehicle floor	Weighed seat (*)				Vehicle floor	
	ax	ay	az	avmax(**)	az	awx	awy	awz	avwmax(***)	awz	
1.											
2.											
3.											

Weighted and linear effective values – B operator (weight kg____height cm_____): a(x,y,z) values in m/s^2 r.m.s.

	Test										**Measurement conditions and measurement duration**
	Linear seat				Vehicle floor	Weighed seat (*)				Vehicle floor	
	ax	ay	az	avmax(**)	az	awx	awy	awz	avwmax(***)	awz	
1.											
2.											
3.											

On the measurements related to the A+B operators	Arithmetic mean:		
	Standard Deviation:		
	Coefficient of Variation:		

Weighted and linear effective values – C operator (weight kg____height cm_____)
[to report if the coeff of total variation is > 20 %]: a(x,y,z) values in m/s^2 r.m.s.

	Test										**Measurement conditions and measurement duration**
	Linear seat				Vehicle floor	Weighed seat (*)				Vehicle floor	
	ax	ay	az	avmax(**)	az	awx	awy	awz	avwmax(***)	awz	
1.											
2.											
3.											

(*) = mandatory fields
(**) = avmax =(1.4 x ax; 1.4 x ay; az)
(***) = avwmax =(1.4 x awx; 1.4 x awy; awz)

Note: The *a, awx, awy, ay* values shall NOT be multiplied by 1.4

Signature: ________________