Introduction

Vibrations acting on the human body are called human vibration. The main purpose of measuring human vibration is the prevention of health risks and the evaluation of comfort, for example in vehicles.

Two categories are distinguished:

- **Hand-Arm Vibrations**, which are induced via the hands into the body. They may cause, for example, circulatory disorder, bone, joint or muscle diseases.
- **Whole-Body Vibrations**, acting via the buttocks, the back and the feet of a sitting person, the feet of a standing person or the back and the head of a recumbent person. Such vibrations may cause backache or damage to the spinal column.

Both types of human vibration are described in international standards:

- **ISO 5349** - Measurement and evaluation of human exposure to hand-transmitted vibration
- **ISO 2631** - Evaluation of human exposure to whole-body vibration
- **ISO 8041** - Human response to vibration. Measuring instrumentation
- **ISO 8662** - Hand-held portable power tools - Measurement of vibrations at the handle
- **ISO 6954** - Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships
- **ISO 10056** - Measurement and analysis of whole-body vibration to which passengers and crew are exposed in railway vehicles
- **ISO 10326** - Laboratory method for evaluating vehicle seat vibration

Practical advice for measurement and evaluation of human vibration can be found in **VDI 2057**.

The subject of human vibration has gained particular importance in Europe since the directive **2002/44/EC** came into effect. It specifies the duties of employers with regard to workers protection.

EU Directive 2002/44/EC

The following text is an abstract of Directive 2002/44/EC of the European Parliament and of the Council dated June 25 2002. The complete text can be downloaded from

http://eur-lex.europa.eu/

The directive lays down minimum requirements for the protection of workers from the risks arising from vibrations. Manufacturers of machines and employers should make an adjustment regarding risks related to exposure to vibration.

The directive lays down the following limit values:

	Hand-Arm Vibration	Whole-Body Vibration
Exposure Action Value	2.5 m/s²	0.5 m/s²
Exposure Limit	5 m/s²	1.15 m/s²

Once the **exposure action value** is exceeded, the employer shall establish and implement a program of technical and and organizational measures intended to reduce to a minimum exposure to mechanical vibration, taking into account in particular:

- Other working methods that require less exposure to mechanical vibration
- Appropriate work equipment of ergonomic design, producing the least possible vibration
- Provision of auxiliary equipment that reduces the risk of injuries, such as protective gloves or special seats
- Appropriate maintenance programs for work equipment
- Design and layout of workplaces
- Adequate information and training to instruct workers to use work equipment correctly and safely
- Limitation of the duration and intensity of the exposure
- Work schedules with adequate rest periods
- Provision of clothing to protect workers from cold and damp

In any event, workers shall not be exposed above the **exposure limit value**. If this should be the case, the employer shall take immediate action to reduce exposure below the exposure limit value.

The methods used may include sampling, which must be representative of the personal exposure of a worker to the mechanical vibration in question.

The assessment of the level of exposure to vibration is based on the calculation of **daily exposure A(8)** expressed as equivalent continuous acceleration over an eight-hour work period. For the determination of A(8) it is not necessary to measure over eight hours. It is sufficient to make short-term measurements during representative work steps. The results are normalized to eight hours. Daily exposure is calculated as follows:

$$A(8)=a_{we}\sqrt{\frac{T_e}{T_0}}$$ Equation 1

where

a_{we} is the energy equivalent mean value of the frequency weighted acceleration during the exposure

T_e is the total duration of exposure during one work day

T_0 is the reference duration of 8 hours

Daily exposure may consist of several activities with different vibration magnitudes. This can be the case if there are longer interruptions in the work process, if the work equipment or its way of use is changed. Resulting daily exposure is calculated:

$$A(8)=\sqrt{\frac{1}{T_0}\sum_{i=1}^{n} a_{wi}^2 T_i}$$ Equation 2

where

a_{wi} is the energy equivalent mean value of the frequency weighted acceleration of activity i

n is the number of activities

T_i is the duration of activity i

T_0 is the reference duration of 8 hours

For **hand-arm vibration** the energy equivalent mean value a_{we} is calculated to ISO 5349. It is the square root of the sum of the squares (vector sum) of the interval rms values a_{wx}, a_{wy} and a_{wz}. The interval rms values are measured as the accelerations in three orthogonal directions with the weighting filter W_h. This vector sum is often called **Total Vibration Value** a_{hv} :

$$a_{we}=a_{hv}=\sqrt{a_{wx}^2+a_{wy}^2+a_{wz}^2}$$ Equation 3

In the case of machines which need to be held with both hands, measurements must be made on each hand. The exposure is determined by reference to the higher value of the two.

For **whole-body vibration** the energy equivalent mean value of acceleration a_{we} (interval rms) is measured separately on three orthogonal axes to ISO 2631-1. For seated persons the following weighting filters and multiplying factors are applied:

X axis:	Filter W_d	Multiplying factor $k_x = 1.4$
Y axis:	Filter W_d	Multiplying factor $k_y = 1.4$
Z axis:	Filter W_k	Multiplying factor $k_y = 1$

The highest one of the three values is inserted as a_{we} in the calculation of A(8).

If no dominant axis of vibration exists, the energy equivalent mean value of acceleration a_{we} may also be calculated as vibration total value a_{hv}, where the multiplying factors k_x, k_y and k_z are to be used:

$$a_{we}=a_{hv}=\sqrt{k_x^2 a_{wx}^2+k_y^2 a_{wy}^2+k_z^2 a_{wz}^2}$$ Equation 4