

Whole-body vibration

**Guideline to the implementation of Directive
2002/44/EC for earth-moving machinery**



LIEBHERR

Preface

On 6 July 2005, the Directive 2002/44/EC of the European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) came into force.

The directive obliges operators of earth moving machinery for every driver to:

- Determine and assess risks caused by whole-body vibrations
- Document the exposure to vibrations
- Keep the risk assessment up-to-date on a regular basis
- Adopt provisions aimed at reducing the exposure
- Provide worker information and training on the low-vibration operation of earth-moving machinery
- Adopt provisions to ensure the appropriate health surveillance of drivers

Since the exposure limit values for hand-arm vibrations at the driver seat of an earth moving machine are generally under-run, these guidelines will only deal with whole-body vibrations affecting the driver.

As correct measurement of single exposure cycles is difficult, not reproducible, uneconomical and only required if no corresponding data is available for the specific operating conditions, this guideline is designed to provide a simplified method to determine and assess the daily exposure of drivers to vibrations.

With this brochure, Liebherr wants to provide you with a guideline that will help you to specifically comply with the demands of the directive in a short time.

For more detailed information on whole-body vibrations on the internet see the links provided on page 20.



1 Influences of whole-body vibrations on driver exposure

2 Provisions aimed at reducing exposure to vibrations

3 Legal requirements

4 Determination and assessment of daily exposure to vibrations (simplified method)

5 Practical examples



1 Influences of whole-body vibrations on driver exposure

Driver exposure to vibrations can significantly be influenced by the driver and operator. It depends on the following factors:

Driver:	Driving style Operation Training
Construction site:	Driving route Grounds Material
Machine:	Machine type Equipment Seat Suspension/Damping systems Condition/Maintenance

To a great extent, the driver determines the current exposure to vibrations himself since he can choose factors as speed, operating mode and driving route. In addition, driver exposure to vibrations is influenced by machine type, equipment, maintenance condition and seat type.

The daily driver exposure to vibrations depends on vibration values as well as duration of exposure.



2 Provisions aimed at reducing exposure to vibrations

- Correct use of machines
 - High-quality seat and its correct adjustment
 - Fine maintenance condition of the machine
 - Correct operation of the machine
 - Appropriate driving speed
 - Good ground conditions
 - Use of additional suspension/damping systems
-
- It is highly recommended to follow the safety instructions provided by the machine manufacturer. Only use appropriate machines, equipment and additional devices for the task at hand.
-
- In case of re-fitting of the driver seat, only use seats complying with ISO 7096:2000. All original seats are provided in accordance with ISO 7096:2000. As the seat has to be individually adjusted for every driver, it is recommended to consider the following aspects regarding seating comfort:
 - Height and weight adjustment
 - Ideal damping adjustment
 - Correct inclination adjustment
 - Use of additional options such as lumbar support
-
- Carry out regular maintenance checks of your machines, particularly of tyre pressure, chain tension, brakes, steering and mechanical linkages.
-
- Avoid jerky operation of machine and working equipment. Avoid jerky steering, braking and accelerating.
-
- Adapt the driving speed to the road conditions.
 - Adapt your driving speed to longer distances
 - Decelerate if you drive on rough grounds
 - Drive round obstacles and avoid driving on extremely rough grounds
-
- Try to maintain a good condition of the grounds the machine works and drives on.
 - Remove big stones and obstacles
 - Avoid and fill up holes
 - Keep appropriate machines for ground improvement
 - Allow enough time for such measures.
-
- Use additional systems such as ride control for machines with a high driving rate. If no additional system is available, avoid building up of the machine by reducing speed.

3 Legal requirements

- The EU Directive 2002/44/EC defines the daily driver exposure to vibrations with two limit values:
 - Action value 0.5 m/s^2
 - Limit value 1.15 m/s^2

Note: Some EU member states may have stricter limit values.

- Once the exposure action values are exceeded, the operator of construction machinery shall implement the following measures:
 - Establish technical and organisational measures intended to reduce to a minimum the exposure to mechanical vibration (see chapter 2)
 - Provide adequate information and training to instruct drivers to use work equipment correctly and safely in order to reduce their exposure to mechanical vibration to a minimum
 - Adopt provisions to ensure the appropriate health surveillance of drivers
- If the exposure limit value is exceeded, the operator of construction machinery shall implement the following measures:
 - Take immediate action to reduce exposure below the exposure limit value
 - If necessary, reduce working hours

The assessment of the daily level of exposure to vibration is based on the following calculation of vibration values and duration of exposure in different operating cycles. The results can either be displayed in m/s^2 or in a system of points.

1. Simplified determination using a system of points
2. Calculation using the attached daily vibration calculator (CD)
3. Online calculation on the internet (see links on page 20)

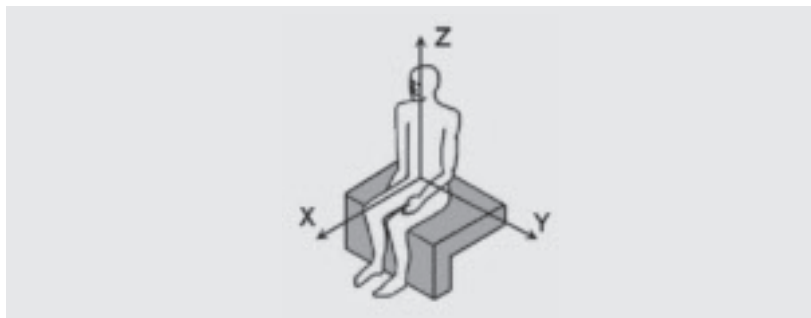
The following pages describe a simple system of points to determine and assess the daily exposure of a driver to vibrations without any measurement or calculations.

4 **Determination and assessment of daily exposure to vibrations** (simplified method)

Since the daily driver exposure to vibration depends on the vibration values as well as on the duration of exposure, both factors need to be determined.

Determination of the vibration values of different operating cycles

The driver vibration values in different operating cycles are determined using the chart on page 8/9. The chart contains average vibration values of construction machines and their typical application areas. The vibration values are given for the three main directions x, y and z.



The operating conditions for the machinery are divided into three stages: light, normal and hard operating conditions. The x, y and z axis need to be assigned to the same condition. The exposure of machinery and drivers can be divided into the following categories:

Light conditions (L)

Experienced driver, level road surface, loose material ...

Normal conditions (N)

Proficient driver, level road surface ...

Hard conditions (H)

Inexperienced driver, rough use of machinery ...

Vibration values for different construction vehicles

machine family	machine type	typical operating cycle	Vibration values in m/s ² at operating conditions Light , Normal and Hard								
			x-axis			y-axis			z-axis		
			L	N	H	L	N	H	L	N	H
rollers	vibratory single-drum roller	compact (stones)	0.30	0.47	0.64	0.31	0.53	0.75	0.29	0.41	0.53
		compact (sand)	0.21	0.29	0.37	0.11	0.28	0.45	0.17	0.28	0.39
	tandem vibratory roller	asphalt with vibration	0.22	0.33	0.44	0.32	0.40	0.48	0.34	0.48	0.62
		asphalt without vibration	0.22	0.35	0.48	0.23	0.43	0.63	0.17	0.36	0.55
dumpers	articulated compact dumper	operating cycle	0.41	0.49	0.57	0.54	0.61	0.68	0.43	0.48	0.53
	articulated frame dumper	loading process	0.12	0.29	0.46	0.18	0.41	0.64	0.08	0.24	0.40
		unloading process	0.24	0.49	0.74	0.09	0.42	0.75	0.12	0.30	0.48
		driving with load	0.43	0.64	0.85	0.60	0.89	1.18	0.46	0.67	0.88
		driving without load	0.56	0.82	1.08	0.76	1.02	1.28	0.53	0.81	1.09
	rigid frame dumper	loading process	0.01	0.20	0.39	0.05	0.22	0.39	0.02	0.21	0.40
		unloading process	0.23	0.37	0.51	0.24	0.37	0.50	0.25	0.33	0.41
		driving with load	0.40	0.61	0.82	0.39	0.63	0.87	0.48	0.82	1.16
		driving without load	0.53	0.73	0.93	0.48	0.73	0.98	0.54	0.87	1.20
	excavator	compact crawler excavator	excavate	0.14	0.33	0.52	0.09	0.21	0.33	0.09	0.19
with hydraulic breaker			0.29	0.49	0.69	0.15	0.28	0.41	0.19	0.36	0.53
transfer			0.28	0.45	0.62	0.21	0.39	0.57	0.34	0.62	0.90
crawler excavator		excavate	0.20	0.44	0.68	0.11	0.27	0.43	0.13	0.30	0.47
		with hydraulic breaker	0.23	0.53	0.83	0.13	0.31	0.49	0.27	0.55	0.83
		extraction work	0.44	0.65	0.86	0.27	0.42	0.57	0.29	0.61	0.93
		transfer	0.29	0.48	0.67	0.12	0.32	0.52	0.56	0.79	1.02
mobile excavator		excavate	0.26	0.52	0.78	0.13	0.35	0.57	0.16	0.29	0.42
		transfer	0.29	0.41	0.53	0.33	0.53	0.73	0.42	0.61	0.80

machine family	machine type	typical operating cycle	Vibration values in m/s ² at operating conditions Light , Normal and Hard								
			x-axis			y-axis			z-axis		
			L	N	H	L	N	H	L	N	H
loader	backhoe loader	excavate	0.19	0.28	0.37	0.10	0.26	0.42	0.14	0.20	0.26
	compact skid-steer loader	load & carry	0.56	0.86	1.16	0.40	0.73	1.06	0.58	0.93	1.28
	crawler skid-steer loader	v-mode	0.91	1.21	1.51	0.16	1.00	1.84	0.50	0.82	1.14
	compact wheel loader	load & carry	0.67	0.94	1.21	0.57	0.86	1.15	0.52	0.65	0.78
	wheel loader	load & carry	0.61	0.84	1.07	0.61	0.81	1.01	0.38	0.52	0.66
		extraction work	0.80	1.27	1.74	0.66	0.97	1.28	0.34	0.81	1.28
		transfer	0.43	0.76	1.09	0.56	0.91	1.26	0.32	0.49	0.66
		v-mode	0.70	0.99	1.28	0.52	0.84	1.16	0.40	0.54	0.68
	crawler loader	load & carry	0.77	0.89	1.01	0.51	0.67	0.83	0.42	0.52	0.62
		transfer	0.40	0.58	0.76	0.37	0.49	0.61	0.45	0.60	0.75
		v-mode	0.83	1.24	1.65	0.58	0.93	1.28	0.45	0.63	0.81
telescopic loader	telescopic loader*	operating cycle*	0.63	0.82	1.01	0.45	0.53	0.68	0.39	0.60	0.81
grader	grader	grade	0.43	0.74	1.05	0.33	0.58	0.83	0.39	0.70	1.01
		with rear-mounted ripper	0.85	1.25	1.65	0.78	1.19	1.60	0.74	1.02	1.30
		transfer	0.44	0.87	1.30	0.40	0.80	1.20	0.63	0.97	1.31
pipelayer	pipelayer	operating cycle	0.12	0.21	0.30	0.12	0.23	0.34	0.10	0.24	0.38
motor grader	motor grader	finish work	0.19	0.41	0.63	0.22	0.48	0.74	0.24	0.38	0.52
		hard work	0.40	0.61	0.82	0.43	0.64	0.85	0.48	0.78	1.08
		transfer	0.14	0.39	0.64	0.11	0.36	0.61	0.24	0.58	0.92
scraper	scraper	operating cycle	0.12	0.21	0.30	0.12	0.23	0.34	0.10	0.24	0.38
landfill compactor	landfill compactor	operating cycle	0.38	0.55	0.72	0.50	0.83	1.16	0.19	0.34	0.49

Source: ISO/TR 25398 Mechanical Vibration; * Liebherr information

These vibration values can be used for all common construction vehicles, independent of the manufacturer.

Other information on vibration values can be obtained from work organizations and state authorities. If you use any other data, quality and accuracy of the values need to be examined.

Determination of the duration of driver exposure to vibration

The daily driver exposure to vibration can either be estimated or measured, using the duration of the individual operating cycles the driver carries out during the day. To define the individual operating cycles, use the chart on page 8/9.

Note: If the drivers are asked about the duration of their exposure to vibration, times are usually overestimated since they tend to include vibration-free periods such as engine idling or waiting periods.

Attention: Vibration-free periods do not constitute an exposure to vibrations and therefore may not be included in the calculations.

Example: The driver of a wheel loader estimates the daily operating time at 7.5 hours. However, only 5 hours of dumping and 1 hour of extraction work can be counted as actual periods of exposure. The remaining 1.5 hours cannot be counted, since the driver was not exposed to any kind of vibration due to waiting periods for the dumper and the detonation.

1 st operating cycle:	Load & Carry	Exposure time: 5 hours
2 nd operating cycle:	Extraction work	Exposure time: 1 hour

Simplified determination and assessment of daily driver exposure to vibration

The aim of this method is to determine and assess the daily driver exposure to vibration using a system of points in which the measured values are replaced by a number of points. The number of points resulting from the individual operating cycles completed during a day are added up to a total value. According to the directive 2002/447EC, the values can be expressed as follows:

Action value (0,5 m/s ²)	100 total points
Limit value (1,15 m/s ²)	529 total points

The total number of achieved points is assigned to a certain colour indicating the operator's need for action (also see the practical examples in chapter 5).

Some EU member states may have stricter limit values. A lower limit value also results in a lower number of total points, which means that the red zone is reached sooner. It is up to you to mark the respective colour codes according to your valid limit values using the following chart:

Limit value in m/s ²	1.15	1.10	1.05	1.00	0.95	0.90	0.85	0.80
Total points	529	484	441	400	361	324	289	256

Vibration values in m/s ² at light, normal and hard operating conditions for x-, y- and z-axis	2.50	31	63	156	313	625	937	1250	1563	1875	2500
	2.45	30	60	150	300	600	900	1201	1501	1801	2401
	2.40	29	58	144	288	576	864	1152	1440	1728	2304
	2.35	28	55	138	276	552	828	1105	1381	1657	2209
	2.30	26	53	132	265	529	794	1058	1323	1587	2116
	2.25	25	51	127	253	506	759	1013	1266	1519	2025
	2.20	24	48	121	242	484	726	968	1210	1452	1936
	2.15	23	46	116	231	462	693	925	1156	1387	1849
	2.10	22	44	110	221	441	662	882	1103	1323	1764
	2.05	21	42	105	210	420	630	841	1051	1261	1681
	2.00	20	40	100	200	400	600	800	1000	1200	1600
	1.95	19	38	95	190	380	570	761	951	1141	1521
	1.90	18	36	90	181	361	542	722	903	1083	1444
	1.85	17	34	86	171	342	513	685	856	1027	1369
	1.80	13	32	81	162	324	486	648	810	972	1296
	1.75	15	31	77	153	306	459	613	766	919	1225
	1.70	14	29	72	145	289	434	578	723	867	1156
	1.65	14	27	68	136	272	408	545	681	817	1089
	1.60	13	26	64	128	256	384	512	640	768	1024
	1.55	12	24	60	120	240	360	481	601	721	961
	1.50	11	23	56	113	225	338	450	563	675	900
	1.45	11	21	53	105	210	315	421	526	631	841
	1.40	10	20	49	98	196	294	392	490	588	784
	1.35	9	18	46	91	182	273	365	456	547	729
	1.30	8	17	42	85	169	254	338	423	507	676
	1.25	8	16	39	78	156	234	313	391	469	625
	1.20	7	14	36	72	144	216	288	360	432	576
	1.15	7	13	33	66	132	198	265	331	397	529
	1.10	6	12	30	61	121	182	242	303	363	484
	1.05	6	11	28	55	110	165	221	276	331	441
	1.00	5	10	25	50	100	150	200	250	300	400
	0.95	5	9	23	45	90	135	181	226	271	361
	0.90	4	8	20	41	81	122	162	203	243	324
	0.85	4	7	18	36	72	108	145	181	217	289
	0.80	3	6	16	32	64	96	128	160	192	256
	0.75	3	6	14	28	56	84	113	141	169	225
	0.70	2	5	12	25	49	74	98	123	147	196
	0.65	2	4	11	21	42	63	85	106	127	169
	0.60	2	4	9	18	36	54	72	90	108	144
	0.55	2	3	8	15	30	45	61	76	91	121
	0.50	1	3	6	13	25	38	50	63	75	100
	0.45	1	2	5	10	20	30	41	51	61	81
	0.40	1	2	4	8	16	24	32	40	48	64
	0.35	1	1	3	6	12	18	25	31	37	49
	0.30	0	1	2	5	9	14	18	23	27	36
	0.25	0	1	2	3	6	9	13	16	19	25
	0.20	0	0	1	2	4	6	8	10	12	16
Minutes	6	12	30	60	120	180	240	300	360	480	
Hours	0.1	0.2	0,5	1	2	3	4	5	6	8	
	Exposure time										

Determination and assessment of daily driver exposure by total number of points

1. Determine the type of machine and the corresponding operating cycles the driver completes during the day.
2. Estimate or measure the duration of exposure for the individual operating cycles. Vibration-free periods may not be counted.
3. Determine whether your driver is exposed to light, normal or hard operating conditions.
4. Determine the vibration values of the individual operating cycles for the x-, y- and z-axis using the chart on page 8/9.
5. Determine the number of points of the individual operating cycles for the x-, y- and z-axis using the chart on page 11. In case of intermediate values, the vibration values should be rounded up.
6. Add up the points for x-, y- and z-axis.
7. The highest point sum of the three axes constitutes the total number of points.
8. Compare the total number of points to the action value and the limit value valid in the respective EU member state.
9. Determine the need for action of the operator of the construction vehicle.

Machine Operating Cycle	Duration of exposure in hours	x-axis in m/s ²	No. of points	y-axis in m/s ²	No. of points	z-axis in m/s ²	No. of points
		x-axis point sum total		y-axis point sum total		z-axis point sum total	
Total number of points: (highest point sum of x-, y- and z-axis)							

5 Practical examples

Note: The practical examples given in this brochure refer to the limit values stated in the directive 2002/44/EC. In case of lower limit values in some EU member states, the red zone is reached sooner.

Example 1 Wheel loader operation

Operating conditions:

- very good working conditions
- level surface
- very experienced driver
- typical operating cycle 1: Load & carry, 3 hours
- typical operating cycle 2: Transfer, 1 hour

Result: Light conditions (L)

Use the vibration values stated for x-, y- and z-axis under light conditions.

Machine Operating Cycle	Duration of exposure in hours	x-axis in m/s^2	No. of points	y-axis in m/s^2	No. of points	z-axis in m/s^2	No. of points
Wheel loader Load & carry	3	0.61 rounded up to 0.65	63	0.61 rounded up to 0.65	63	0.38 rounded up to 0.40	24
Wheel loader Transfer	1	0.43 rounded up to 0.45	10	0.56 rounded up to 0.60	18	0.32 rounded up to 0.35	6
Total number of points: (highest point sum of x-, y- and z-axis)		x-axis point sum total	73	y-axis point sum total	81	z-axis point sum total	30
		81					

Assessment of a total point sum between 0 and 100:

The action value of the vibration exposure is not exceeded.

- If the result is near the action value, appropriate action shall be taken to reduce vibration exposure (see chapter 2).
- Adequate information and training shall be provided to instruct drivers how to reduce their exposure to mechanical vibration

Example 2

Combined wheel loader and crawler excavator operation

Operating conditions:

- normal working conditions
- level surface
- very experienced driver
- typical operating cycle 1: wheel loader v-mode, truck loading, 4 hours
- typical operating cycle 2: crawler excavator, extraction work, 2 hours

Result: Normal conditions (N)

Use the vibration values stated for x-, y- and z-axis under normal conditions.

Machine Operating Cycle	Duration of exposure in hours	x-axis in m/s ²	No. of points	y-axis in m/s ²	No. of points	z-axis in m/s ²	No. of points
Wheel loader v-mode	4	0.99 rounded up to 1.0	200	0.84 rounded up to 0.85	145	0.54 rounded up to 0.55	61
Crawler excavator extraction	2	0.65	42	0.42 rounded up to 0.45	20	0.61 rounded up to 0.65	42
Total number of points: (highest point sum of x-, y- and z-axis)		x-axis point sum total	242	y-axis point sum total	165	z-axis point sum total	103
		242					

Assessment of a total point sum between 101 and limit value:

The action value of the vibration exposure is exceeded.
The limit value is not exceeded.

- The employer shall establish and implement a programme intended to reduce the vibration exposure
- Provisions shall be made to ensure the appropriate health surveillance of drivers

Example 3

Compact skid-steer loader operation

Operating conditions:

- hard working conditions
- uneven surface
- inexperienced driver
- typical operating cycle: Load & carry, 7 hours

Result: Hard conditions (H)

Use the vibration values stated for x-, y- and z-axis under hard conditions.

Machine Operating Cycle	Duration of exposure in hours	x-axis in m/s ²	No. of points	y-axis in m/s ²	No. of points	z-axis in m/s ²	No. of points
Compact skid-steer loader Load & carry	7	1.16 rounded up to 1.20	504	1.06 rounded up to 1.10	424	1.28 rounded up to 1.30	592
Total number of points: (highest point sum of x-, y- and z-axis)		x-axis point sum total	504	y-axis point sum total	424	z-axis point sum total	592
592							

Assessment of a total point sum exceeding the limit value:

The limit value of vibration exposure is exceeded.

- The employer shall take immediate action to reduce exposure below the exposure limit value
- If necessary, working hours have to be reduced.



Required information for documentation

Machine data:	
Date	
Company	
Operating site	
Machine type:	
Machine manufacturer:	
Serial number	
Engine performance (kW)	
Machine mass (t)	
Year of manufacture	
Operating hours	
Machine condition	
Seat type	
Seat manufacturer	
Seat spring system	
Seat, ISO 7096 (y/n)	
Weight adjustment (y/n)	
Spring travel (mm)	
Seat condition	
Tyre type	
Tyre size	
Tyre pressure (bar)	
Track chain (type)	
Track pad width	
Number of grousers per track pad	
Other:	

Driver-related data for a typical working day:

[illegible][illegible]

Driver-related data for a typical working day:

Driver experience

Useful internet links

<http://europa.eu.int/eur-lex/>

http://www.bgm-metallsued.de/fachausschuss/SG_Vibration.php

<http://www.hse.gov.uk/vibration/calculator.htm>

<http://umetech.niwl.se/eng/wbvcalculator.lasso>

Sources

ISO/TR 25398 Mechanical vibrations – Guideline for the assessment of whole-body vibration of earth moving machinery for seated operators using harmonized data measured by international institutes, organizations and manufacturers.

The vibration exposure data stated in this guideline is based on average real measurement results of whole-body vibrations related to practical operating cycles of different machine types and manufacturers.

For more detailed information do not hesitate to contact your Liebherr dealer.

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