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Vibration in hand-held tools — Vibration measurement methods for grinders — Evaluation of round-robin test

Vibration des machines à moteur portatives — Méthodes de mesure des vibrations des meuleuses — Évaluation d'essais Round Robin

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Foreword

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ISO/TR 27609 was prepared by Technical Committee ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*, Subcommittee SC 3, *Pneumatic tools and machines*.

Introduction

At the time of publication of this Technical Report, it was intended that ISO 8662-4, which deals with hand-held grinders, be revised and harmonized with ISO 20643. The latter International Standard requires, among other provisions, that the vibration emission measurements be made in three directions, with the declared values related to the upper quartile of real-use vibration.

A round-robin test was made to gain an idea of the upper limits of real-use vibration and to establish a test method fulfilling the three-direction requirement. Four grinders of different sizes — both with, and without, auto-balancing units — were measured by seven laboratories. Measurements were made according to detailed test instructions. The laboratories were manufacturers and health and safety authorities in Europe.

Two methods were evaluated by the round-robin test: one using a redesigned unbalance disc and the other by grinding on mild steel using standard type 27 grinding wheels.

The result shows that the unbalance disc test method can be used for estimating the real-use vibration as long as the grinder is not fitted with an auto-balancing unit. If such a unit is fitted, the real-use vibration is underestimated by that method. Methods for estimating the real-use vibration level for grinders fitted with auto-balancing units are not discussed in this Technical Report.

A real grinding test is not suitable for obtaining a declared value, as the spread for this method is large. Furthermore, in order to obtain enough data to handle the large spread, the time consumption is unreasonably high.

Vibration in hand-held tools — Vibration measurement methods for grinders — Evaluation of round-robin test

1 Scope

This Technical Report presents an evaluation of a round-robin test of vibration measurement methods for determining vibration in hand-held grinders. The aim of the round-robin test was to establish a test method that could meet the requirement of ISO 20643 for measurement of vibration emissions in three directions, for accordance with the planned-to-be-revised ISO 8662-4.

The value obtained by such a test method must correspond to the highest vibration values likely to occur under typical and normal working conditions of the machine, i.e. the upper quartile of the vibration in real use. This acknowledges that the upper boundary of “typical and normal” conditions can be exceeded by some conditions of “real use”.

Vibration at grinding can mainly be divided into vibration caused by unbalance of the grinding wheel and process vibration generated by the contact between the grinding wheel and the work piece. The unbalance part has been shown to be the greater of the two and ISO 8662-4 is based on this. In this Technical Report, the test method consists of a number of averaged measurements using an unbalance disc, with an unbalance corresponding to the upper limit of the unbalances found among real grinding wheels.

Whereas ISO 8662-4 covers all types of hand-held grinders, the round-robin test presented in this Technical Report was based on grinding with depressed centre-wheels, one of the most common grinding applications.

The types of grinder used in the round-robin test are given in Table 1.

Table 1 — Grinder types and sizes used in test

Type of grinder	Wheel size	
	125 mm (5")	230 mm (9")
Pneumatic	Without auto-balancing unit	With auto-balancing unit
Electric	With auto-balancing unit	Without auto-balancing unit

Two tests of the grinders were made: one using an unbalance disc and the other by real grinding.

The unbalance disc test was made with a disc of new design, with the shape of a depressed centre wheel. One reference disc was sent together with the grinding machines, while the other was locally manufactured by the measuring lab. Grinding was made on mild steel with locally purchased grinding wheels. Detailed test instructions were distributed to the participants before the start of the round-robin test.

2 Symbols and abbreviated terms

See Table 2.

Table 2 — Symbols, abbreviated terms and their units

Symbols and abbreviations [a]	Description	Unit
a_{hv}	Vibration total value of frequency-massed r.m.s acceleration: root sum of squares of the a_{hw} values for the three axes of vibration	m/s^2
a_h	Arithmetic mean value of measurement results of runs and operators: result of test	m/s^2
$C_{V,op}$	Coefficient of variation for test based on ratio of standard deviation for operators(s_{op}) and total mean value for all laboratories	—
$C_{V,R}$	Coefficient of variation of reproducibility for test based on ratio of standard deviation for laboratories(s_R) and total mean value for all laboratories	—
G	Grinding	—
L 1…7	Laboratory making the measurement	—
LD	Locally made unbalance disc	—
M1	125 mm grinder without auto-balancing unit, pneumatically powered	—
M2	125 mm grinder with auto-balancing unit, electrically powered	—
M3	230 mm grinder without auto-balancing unit, electrically powered	—
M4	230 mm grinder with auto-balancing unit, pneumatically powered	—
NL	No-load	—
RD	Reference unbalance disc	—
s_{op}	Standard deviation for operator, adjusted for the mean value of each laboratory: $$s_{op} = \sqrt{\frac{1}{n-1}\sum_i \sum_j \left(a_{i,j} - \overline{a}_i\right)}$$ $a_{i,j}$ value for operator j at laboratory i $\overline{a}_i$ mean value for laboratory i	m/s^2
s_R	Standard deviation of reproducibility for laboratories according to EN 12096:1997, A.10: $$s_R = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} \left(a_i - \overline{a}\right)^2}$$ a_i results achieved at n different laboratories $\overline{a}$ mean value for all laboratories	m/s^2

[a] Other symbols and abbreviated terms are according to ISO 20643:2005.

3 Method

The round-robin test was evaluated by studying the statistics of the data collected from the different tests and labs using the following parameters.

— **Spread between operators**

  This parameter gives a measure of the expected spread on laboratory level for the methods.

— **Spread between laboratories**

  This parameter gives the total spread of the method. It includes the spread from operators, machines and measuring equipment.

— **Repeatability**

  This parameter gives the stability of the method.

— **Correlation between grinding and no-load vibration**

  This parameter indicates in what extent grinding vibrations is dominated by unbalance or not.

In order to be able to compare values from the different sizes and types of grinder, the coefficient of variation — the mean value divided by standard deviation — was used.

Significance tests were made using a double sided t-test with 95 % significance.

4 Description of two test methods evaluated

4.1 Unbalance disc test method

The new test wheel had tighter tolerances, thereby reducing the spread in unbalance from 2 % to 0,5 %. It had a movable unbalance screw instead of a drilled hole, making it possible to vary the unbalance without remounting the disc, and consequently simplifying the measurements and eliminating the uncertainty introduced by loosening of the disc. The disc was shaped as a depressed centre wheel, see Figure 1.

Each lab measured the vibrations using two test wheels: one reference test wheel circulated through all test labs (RD) and one manufactured by the measuring lab (LD).

A feed force equal to that recommended by ISO 8662-4:1994 was applied to the grinder during the test.

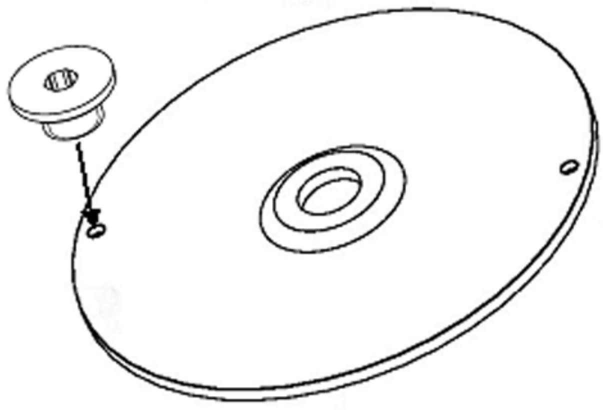


Figure 1 — Sketch of unbalance test disc (unbalance screw enlarged)

4.2 Grinding test method

The grinding test was made on mild steel using depressed centre wheels (type 27). Each test session started with a 10 s no-load measurement followed by 1 min of grinding and ending with a 10 s no-load measurement. The mean value of the no-load measurements was taken as the estimated unbalance contribution to the vibration during grinding. An example test measurement set-up is shown in Figure 2.

For each grinder, five grinding wheels were used, each operator grinding once with each wheel. According to the test instructions (see Annex A), the grinding was made at the grinder's maximum power by maximizing the amount of sparks from the grinding process. The manner in which this was done differed from lab to lab.

Photo: Health and Safety Laboratory, UK

Figure 2 — Example of test set-up for grinding test

5 Results

5.1 General

During the round-robin test, the reference unbalance disc and screws were damaged, and thus could not actually be used as the reference. However, in some cases they are reported separately.

On the M1 grinder, the hose was replaced by a quick coupling during the round-robin test. As a consequence, the inertia and mass of the machine were changed, possibly affecting the vibration level. However, no difference was detected that can be related to this change.

In some cases, large brackets were mounted at the support handle for attaching the feed force wire, thereby also changing the inertia and mass of the machine. As with the case of quick coupling, no signs of differences have been found that can be attributed to this change.

Grinder M1 has a resonant support handle, making the grinder very sensitive to unbalance forces and damping from the operator’s hand. Grip forces were therefore an important, but not recorded, parameter for the vibration value from this grinder.

5.2 Spread of methods

The spread gives an indication of the repeatability and reproducibility of the test methods. The results are presented in the following tables.

5.2.1 Unbalance disc test

The results from the unbalance disc test are separately presented for LD and RD, even though RD was changed during the test round and cannot be used as reference disc. The result for both discs is presented in the “Total” row. See Tables 3 and 4.

Table 3 — Emission values and standard deviations — Unbalance disc test

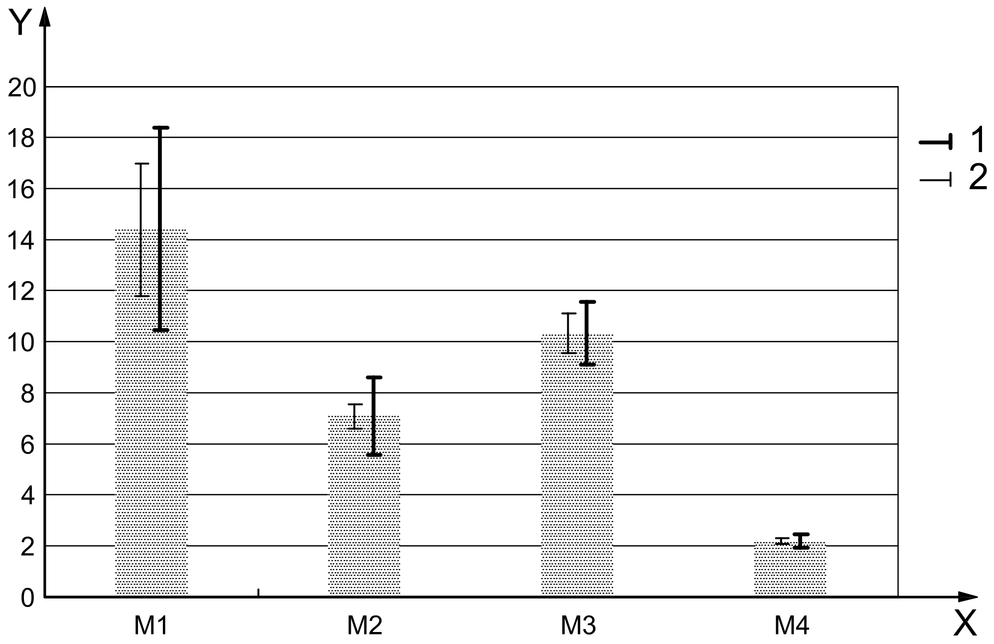
		Max. handle			Support handle			Throttle handle		
		a_h m/s^2	s_{op} m/s^2	s_R m/s^2	a_h m/s^2	s_{op} m/s^2	s_R m/s^2	a_h m/s^2	s_{op} m/s^2	s_R m/s^2
M1	LD	14,33	2,65	3,75	14,33	2,65	3,75	7,34	0,33	1,05
	RD	14,68	2,88	4,59	14,68	2,88	4,59	7,16	0,37	0,81
	Total	14,40	2,58	3,98	14,40	2,59	3,98	7,29	0,30	1,06
M2	LD	7,58	0,47	1,84	5,10	0,58	0,64	7,58	0,47	1,84
	RD	6,99	0,59	1,44	4,78	0,62	0,97	6,99	0,59	1,44
	Total	7,08	0,50	1,51	4,84	0,57	0,95	7,08	0,50	1,51
M3	LD	10,60	0,88	0,91	6,74	0,37	0,62	10,60	0,88	0,91
	RD	9,82	0,54	1,49	6,50	0,30	0,18	9,82	0,54	1,49
	Total	10,23	0,76	0,98	6,63	0,33	0,61	10,23	0,76	0,98
M4	LD	2,25	0,08	0,30	2,06	0,08	0,25	2,23	0,08	0,40
	RD	2,18	0,12	0,26	2,10	0,11	0,25	2,15	0,13	0,29
	Total	2,19	0,11	0,28	2,09	0,07	0,26	2,18	0,11	0,32

A good measure of repeatability and reproducibility are, respectively, the coefficient of variation for operators and the coefficient of variation for the laboratory, presented in Table 4.

Table 4 — Coefficient of variation — Unbalance disc test

		Max. handle			Support handle			Throttle handle		
		$C_{V,op}$	$C_{V,R}$	Ratio	$C_{V,op}$	$C_{V,R}$	Ratio	$C_{V,op}$	$C_{V,R}$	Ratio
M1	LD	0,18	0,26	0,70	0,18	0,26	0,70	0,04	0,14	0,31
	RD	0,20	0,31	0,63	0,20	0,31	0,63	0,05	0,11	0,46
	Total	0,18	0,28	0,65	0,18	0,28	0,65	0,04	0,15	0,28
M2	LD	0,06	0,24	0,26	0,11	0,13	0,91	0,06	0,24	0,26
	RD	0,08	0,21	0,41	0,13	0,20	0,64	0,08	0,21	0,41
	Total	0,07	0,21	0,33	0,12	0,20	0,60	0,07	0,21	0,33
M3	LD	0,08	0,09	0,97	0,05	0,09	0,60	0,08	0,09	0,97
	RD	0,05	0,15	0,36	0,05	0,03	1,67	0,05	0,15	0,36
	Total	0,07	0,10	0,78	0,05	0,09	0,54	0,07	0,10	0,78
M4	LD	0,04	0,13	0,27	0,04	0,12	0,32	0,04	0,18	0,20
	RD	0,06	0,12	0,46	0,05	0,12	0,44	0,06	0,13	0,45
	Total	0,05	0,13	0,39	0,03	0,12	0,27	0,05	0,15	0,34
Average		0,09	0,19	0,44	0,10	0,16	0,54	0,06	0,15	0,36

The coefficient of variation of reproducibility is about 25 % to 30 % for the 125 mm grinders and 10 % to 15 % for the 230 mm grinders. A small value indicates a good reproducibility. The unbalance disc method has, based on all unbalance disc measurements in this round-robin test, a $C_{V,R}$ value of 0,2. The result for each grinder is shown in Figure 3.



Key

X grinder

Y a_h, m/s^2

1 spread, lab

2 spread, operator

NOTE Two spread measures are presented: that between the operators and that between the different laboratories.

Figure 3 — All unbalance disc test method measurement results — Average value and spread for all grinders

By taking the ratio between the total spread and operator spread, an estimate of the operators' contribution to the total spread can be obtained. For this method, the operator contributes 50 % to the total spread, which is why the spread in unbalance of the unbalance disc is negligible. The spread of unbalance calculated theoretically, with the tolerances given for the test tool, is less than 2 % compared to the operator spread.

5.2.2 Grinding test

The results from the grinding test are presented in Tables 5 and 6 as the total average for all measurements on each grinder.

Table 5 — Emission values and standard deviations — Grinding test

		Max. handle			Support handle			Throttle handle		
		a_h m/s^2	s_{op} m/s^2	s_R m/s^2	a_h m/s^2	s_{op} m/s^2	s_R m/s^2	a_h m/s^2	s_{op} m/s^2	s_R m/s^2
M1	G	7,28	1,02	2,46	7,28	1,02	2,46	4,61	0,73	2,26
	NL	8,97	1,40	2,91	8,97	1,40	2,91	4,82	0,41	1,96
M2	G	5,43	0,89	2,43	4,66	0,89	2,34	4,99	0,58	1,72
	NL	4,84	0,34	1,19	3,99	0,35	0,76	4,84	0,35	1,39
M3	G	9,42	1,05	1,59	7,75	0,96	1,84	9,31	0,88	1,21
	NL	5,95	0,59	1,44	5,49	0,51	1,57	5,86	0,50	1,23
M4	G	3,48	0,43	1,00	3,48	0,43	1,00	2,83	0,28	0,95
	NL	1,75	0,20	0,26	1,68	0,17	0,29	1,65	0,19	0,25

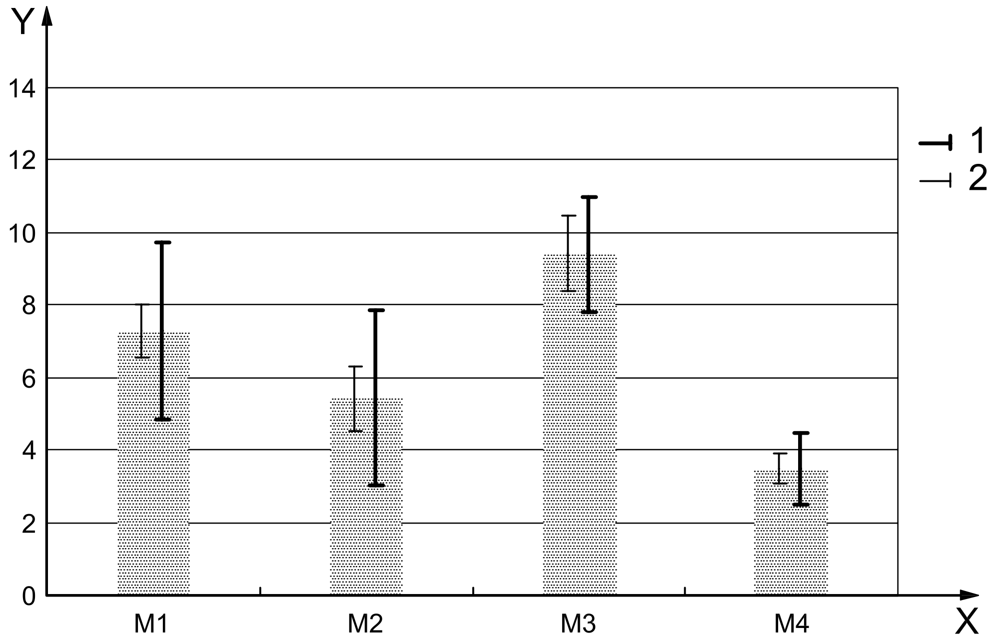
Table 6 — Coefficient of variation — Grinding test

		Max. handle			Support handle			Throttle handle		
		$C_{V,op}$	$C_{V,R}$	Ratio	$C_{V,op}$	$C_{V,R}$	Ratio	$C_{V,op}$	$C_{V,R}$	Ratio
M1	G	0,14	0,34	0,41	0,14	0,34	0,41	0,16	0,49	0,41
	NL	0,16	0,32	0,48	0,16	0,32	0,48	0,09	0,41	0,48
M2	G	0,16	0,45	0,37	0,19	0,50	0,38	0,12	0,34	0,38
	NL	0,07	0,25	0,29	0,09	0,19	0,46	0,07	0,29	0,46
M3	G	0,11	0,17	0,66	0,12	0,24	0,52	0,09	0,13	0,52
	NL	0,10	0,24	0,41	0,09	0,29	0,32	0,09	0,21	0,32
M4	G	0,12	0,29	0,43	0,12	0,29	0,43	0,10	0,34	0,43
	NL	0,11	0,15	0,77	0,10	0,17	0,58	0,12	0,15	0,58
Average		0,12	0,28	0,44	0,13	0,29	0,44	0,10	0,29	0,34

The coefficient of variation of reproducibility was about 35 % for the 125 mm grinders and 20 % to 25 % for the 230 mm grinders.

Based on all grinding measurements in the round-robin, the grinding test had a $C_{V,op}$ value of 0,3. The result for each grinder is shown in Figure 4.

The ratio between the total and the operator spread is in the same range as for the unbalance disc test, i.e. 2.



Key

X grinder

Y a_h, m/s^2

1 spread, lab

2 spread, operator

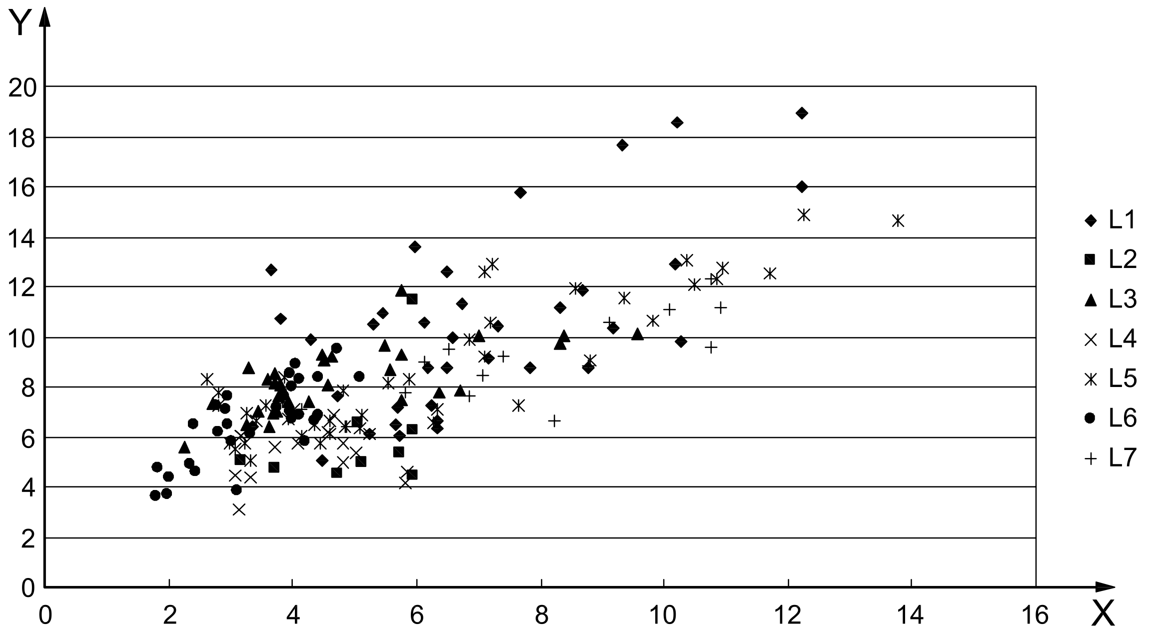
NOTE Two spread measures are presented: that between the operators and that between the different laboratories.

Figure 4 — All grinding test method measurement results — Average value and spread for all grinders — Maximum handle

5.2.3 Correlation between no-load and grinding vibration

One prerequisite for using the unbalance disc test method to estimate vibration at grinding is that the grinding vibration is dominated by the grinding wheel's unbalance. This can be verified by looking at the correlation between no-load and grinding vibration.

As shown in Figure 5, there is a correlation between no-load and grinding vibration for the M3 grinder without an auto-balancing unit.



Key

X no-load vibration, a_{hv}, m/s^2

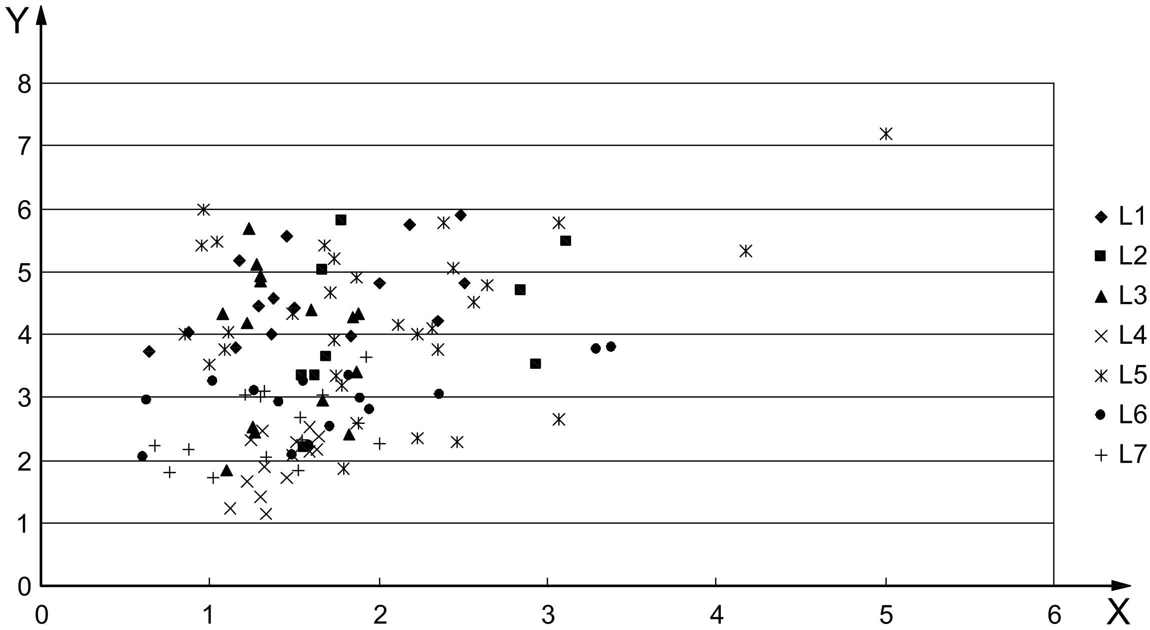
Y grinding vibration, a_{hv}, m/s^2

NOTE Even though the spread is large, a correlation can be seen between no-load and grinding.

Figure 5 — All no-load values vs. grinding vibration for M3 — Support handle

M4 does not show any signs of correlation between no-load and grinding, see Figure 6.

If the auto-balancing unit is badly designed, there can also be a correlation between no-load and grinding vibration.



Key

X no-load vibration, a_{hv}, m/s^2

Y grinding vibration, a_{hv}, m/s^2

NOTE In this case there is no correlation between no-load and grinding.

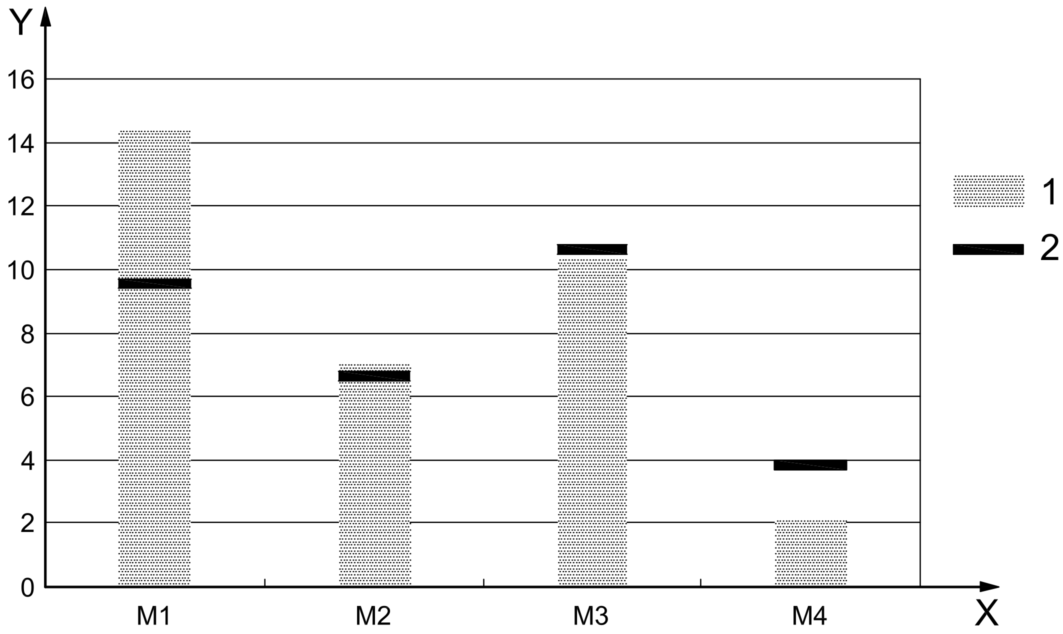
Figure 6 — All no-load values vs. grinding vibration for M4 — Support handle

5.3 Unbalance disc test for simulating real grinding

According to ISO 20643, a test method should result in a vibration value comparable to the upper quartile of real use vibration. To test if that requirement can be fulfilled using the unbalance disc test method, the result from the unbalance disc test was compared to the upper quartile vibration level from the grinding test.

As can be seen from Figure 7, the unbalance disc test values lie over the upper quartile vibration for grinding with grinders without auto-balancing units, with a few exceptions. Thus, the unbalance disc test method *can* be used for estimating the vibration at real grinding.

Grinders with auto-balancing units tested with unbalance disc tend to underestimate the vibration in real use; therefore, an alternative method should be derived for them.



Key

X grinder

Y a_h, m/s^2

1 Al-disc

2 3rd quartile grinding

NOTE The only grinder that clearly lies under the upper quartile limit is M4, fitted with an auto-balancing unit.

Figure 7 — Emission value related to upper quartile for grinding — Maximum handle

5.4 Measurements repeated over time

The repeatability over time is presented in Tables 7 to 10. It can also be used as a measure of repeatability of the methods, in addition to the spread between operators. Four laboratories repeated the test on grinder M3. The time between the first and second measurements was about a week.

Table 7 — Repeat of unbalance disc method for grinder M3 by four laboratories

	Significant difference between measurements 1 and 2 — One to two weeks between tests	
	Support handle	Throttle handle
L1	No	No
L3	No	No
L5	No	No
L6	No	No

Table 8 — Repeat of grinding test for grinder M3 made by four laboratories

	Significant difference between measurements 1 and 2 — One to two weeks between tests			
	No-load		Grinding	
	Support handle	Throttle handle	Support handle	Throttle handle
L1	No	No	No	No
L3	No	No	No	No
L5	No	No	No	No
L6	No	No	No	No

Laboratory L5 repeated the entire round-robin test about a year after the first test. There was no significant difference, at a 95 % significance level, between the results of the two unbalance disc tests. However, there were significant differences between the first and second grinding tests, in all cases except for those of the M4 grinder (see Table 10).

Table 9 — Repeat of entire round-robin test by Laboratory 5 — Unbalance disc test

	Significant difference between measurements 1 and 2 — Approx. one year between tests	
	Support handle	Throttle handle
M1	No	No
M2	No	No
M3	No	No
M4	No	Yes

Table 10 — Repeat of entire round-robin test by Laboratory 5 — Grinding test

	Significant difference between measurements 1 and 2 — Approx. one year between tests			
	No-load		Grinding	
	Support handle	Throttle handle	Support handle	Throttle handle
M1	Yes	Yes	Yes	Yes
M2	Yes	Yes	Yes	Yes
M3	Yes	Yes	Yes	Yes
M4	Yes	Yes	No	No

6 Conclusion

6.1 Unbalance disc test

The spread between operators, the smallest detectable spread in this test, is much higher than the theoretical spread from the unbalance wheel itself. Thus, it would be possible to loosen the tolerances of, for example, the mass of the unbalance screws or continue to use the current type of unbalance disc where the unbalance is made by a hole in the disc.

The result of this method corresponds to the upper quartile of the vibration under the grinding test for grinders without auto-balancing units. It does not apply to grinders fitted with auto-balancing units; therefore, it is recommended that additional information be obtained from real grinding or other suitable methods.

6.2 Grinding test

The spread at grinding is 50 % to 100 % higher than the spread with test using the unbalance disc. The difficulties using the same grinding techniques are probably contributing to this large spread. Thus real grinding is not suitable as a test method for estimating the vibration in real-use.

6.3 Repeatability

Test with unbalance disc gives good repeatability in all repeatability tests here except for the 230 mm grinder with auto-balancing unit. Though, it is already noticed that unbalance disc test is not the best method for vibration testing of grinders with auto-balancing units. Grinding/no-load test can be repeated at the same measurement occasion but gives poor repeatability when repeated with longer time between the tests.

Annex A
(informative)

Test instructions — "Instruction for participants in the 2003 round-robin test on grinders. The aim is to evaluate the proposed changes to ISO 8662-4:1994 in document ISO/TC 118/SC 3/WG 3 N211"

A.1 Preparation of the tools

A.1.1 Air installation

See the instruction manual supplied with the tool to obtain information regarding recommended hose and nipples. For the test, use the supplied nipple and hose clamp. For the test, the hose connected to the tool shall be at least 2 m long from the tool to the first coupling. This is important to avoid influence on the weight of the tool.

GTG 40 shall have a 16 mm hose. The KL 111 shall have a 13 mm hose. Alternatively, use the hoses supplied with the test tools.

A.1.2 Electrical installation

See the instruction manual supplied with the tool for proper installation.

A.1.3 Wheel mounting

Read the instruction manual supplied with the tool for proper mounting of the wheel. It is important that the manufacturer's recommendations for type of flanges and tightening torque are followed.

A.2 Transducers and measurement system

A.2.1 Transducer mounting

The traducers shall be mounted according to the text of the draft revised version of ISO 8662-4. For this round-robin test, the mass of the mounting block with transducers mounted shall not exceed 18 g.

A.2.2 Coordinate system location

The coordinate systems on both handles shall be located according to the draft ISO 8662-4.

A.3 Measurements with test wheel

A.3.1 Warning notice

The test-wheels used in the round-robin test are not of the final design. The unbalance bolts shall be tightened to 8 m. If a bolt comes off during test is can cause severe injuries. Therefore, avoid having personnel in the region where they can be hit by a screw coming loose.

A.3.2 The test wheel

A.3.2.1 Manufacturing

The test wheels shall be manufactured to the specifications on the supplied drawings. Observe that the distances from the centre of the wheel to the centre of the holes are the most critical measures. Most important is that the distance is the same on both sides.

The bolts shall be manufactured according to the drawings to get a weight slightly higher than the final. Weight is then adjusted with a precession scale.

A.3.2.2 Balancing of the wheel

It is normally not necessary to balance the test wheels. Manufactured to the tolerances on the drawings, the new wheel has a precision 5 times better than the present wheel. If the proper equipment is available, measure and report the unbalance of the test wheel.

A.3.2.3 Calibration of unbalance weights

The weights shall be filed down to the correct weight. Measure the weight using a scale with precision better 0,01 g. File off material from the head until you reach the weight indicated on the drawing.

Check that the weight supplied with the pre-manufactured wheel shows the same weight. If there is a difference, report that in the test result. Do not adjust the weight of the pre-manufactured weights.

A.4 Feed force

Use the force given in the table in the draft ISO 8662-4. Apply the force between the two holes used to mount the support handle. Report if the force comes from a weight or from a scale.

A.4.1 Test procedure

To evaluate the repeatability of the method, each lab should ideally repeat all measurements twice. In this test, we restrict the repeatability test to the Flex 230 mm tool. Remove the test wheel and transducers from the tool before repeating the measurements on the Flex tool. Use the same operators. Repeat the test for both the locally manufactured test wheel and the test wheel supplied with the tool.

The test procedure is described in Table A.1. Do not take the wheel off until the test has been completed and all 21 measurements have been collected.

Measurements according to the above table shall be done for both the locally manufactured test wheel and the wheel sent with the tools. For the Flex 230 mm the whole test shall be repeated to evaluate the repeatability of the method.

Table A.1 — Test procedure

Test	Operator	Test wheel	Unbalance weight
1	1	No	No
2	1	Yes	No
3	1	Yes	Pos. 1
4	1	Yes	Pos. 2
5	2	Yes	No
6	2	Yes	Pos. 1
7	2	Yes	Pos. 2
8	3	Yes	No
9	3	Yes	Pos. 1
10	3	Yes	Pos. 2
11	3	No	No
12	1	Yes	No
13	1	Yes	Pos. 1
14	1	Yes	Pos. 2
15	2	Yes	No
16	2	Yes	Pos. 1
17	2	Yes	Pos. 2
18	3	Yes	No
19	3	Yes	Pos. 1
20	3	Yes	Pos. 2
21	2	No	No

A.4.2 Additional measurements (optional)

Enlarging the number of operators to five instead of three operators would increase the possibilities for evaluating operator influence.

Repeated tests for tools other than the Flex with the same or other operators will increase our possibility to evaluate the repeatability of the method. If repeated tests are performed, the test wheel should preferably be taken off and remounted on the tool between each complete test. Report if the wheel was kept on the tool or remounted.

For at least the GR tool, it would be interesting if a second test is performed with two sets of accelerometers on the support handle, one in each end of the grip zone. The two transducers shall be positioned symmetrically around the point used for the measurements with one transducer. The distance between the transducers shall be 100 mm.

A.5 Measurement in simulated real grinding

A.5.1 Personal protection

Grinding without proper personal protection can cause injury. In a test situation like this it is easy to be careless and skip parts of the personal protection. Use an overall made of a non-inflammable material, a leather apron that is long enough to cover your front side including shoes, leather gloves, ear protection, eye protectors and a protective helmet with visor.

A.5.2 General information

To evaluate the repeatability of the method each lab should ideally repeat all measurements twice. In this test we restrict the repeatability test to the Flex 230 mm tool.

This test procedure has been devised for the measurement of vibration from grinders during real operation. The simulated real grinding procedure is designed to provide additional data that, in combination with the values obtained with the test wheel, can provide values that are indicative of the vibration from the tool during real use.

Measurements are taken in three orthogonal axes on both gripping zones of the tool. The origin of the orthogonal axes is less than 10 mm from the surface of the tool handle. It is essential for the round-robin test that the exact same transducer positions and directions are used in both the test with the artificial wheel and the grinding test.

The vibration emission of each tool according to the method proposed in the new draft should be measured before the real grinding tests are performed.

A.5.3 Test Wheels

A batch of five mild steel grinding wheels should be purchased locally. With the following specification:

$n \times 6 < t < 7{,}5$ mm $\times$ $22 < d < 22{,}3$ mm (where n is the maximum diameter of the wheel for the grinding machine — e.g. 125 mm or 230 mm, t is the thickness and d is the diameter of the centre hole),

course, medium-to-hard-grade reinforced resinoid grinding wheels suitable for steel (e.g. A24R-BF).

If the necessary equipment is available, it would be informative if the unbalance of the test wheel is measured before and after the completed test.

A.5.4 Test work piece

A piece of mild steel (density 7 850 kg/m^3) of dimensions 20 mm $\times$ 60 mm $\times$ 400 mm is used for all the tests. The work piece is rigidly clamped with the 20 mm $\times$ 400 mm surface facing upwards.

A.5.5 Tool operation

The grinder should be operated at the manufacturers recommended pressure or voltage. The grinder should be configured for grinding operations with the wheel fitted by a competent person. During the grinding measurements the wheel should be positioned at a typical operational angle for grinding operation (20° to 40° above the work piece). Operators should be asked to operate the tools to maximize the sparks from the work piece (i.e. most efficient operation). Operators should not be constrained in terms of feed force or operator technique.

When possible, it would be informative if the air consumption, for the air tools, and the power input, for the electrical tools, are measured during the test.

A.5.6 Test procedure

For the Flex 230 mm the whole test shall be repeated to evaluate the repeatability of the method. Remove the wheel and transducers form the tool before repeating the measurements on the Flex tool. Use the same operators. Use a new set of wheels.

1) Fit wheel 1 to the tool and measure the free running vibration for approximately 30 s.

2) Perform grinding on the steel bar clamped in a vice for approximately 1 min, maintaining a pressure that keeps the tool operating at its point of greatest efficiency (i.e. maximum amount of sparks from the grinding process). Ask the operator to avoid stalling the tool or allowing the tool to run too fast.

3) Following the grinding, measure the free running vibration again for approximately 30 s.

4) Repeat steps 1) to 3) for two other operators keeping the wheel fitted to the tool.

5) Repeat steps 1) to 4) for the other four wheels (five wheels and three operators used in total).

If the necessary equipment is available, interesting information regarding the efficiency of the grinding can be collected if the weight of the wheel and the work piece are measured before and after the test with each wheel (points 1 to 4 above).

A.5.7 Additional tests

Repeated tests for more tools than the Flex 230 mm will provide valuable information about repeatability.

For the purpose of better understanding of how the unbalance develops during grinding, it would be most useful to have data from longer grinding tests — preferably until the wheel is completely worn down. If the grinding test could be prolonged for at least some of the wheels, we would gain valuable information. Use exactly the same procedure as for the normal grinding test. Keep the wheel on the tool for the whole test because that is how the wheel is normally used.

For at least the GR tool, it would be interesting if a second test is performed with two sets of accelerometers on the support handle, one in each end of the grip zone.

A.6 Test report

A.6.1 General

All evaluation of raw data is voluntary. An evaluation of all data will be done in the end of the round-robin test.

A.6.2 Raw data

The data from all six axes can be reported in the sheet supplied. Both grinding and no-load values must be reported. Frequency spectra from grinding and free running can add valuable information for the understanding of differences between results from different labs. If your measurements contain frequency analysis, please keep that information available for later use. Please use a digital camera to document your accelerometer mounts and all other information that might be of interest.

A.6.3 Test wheel evaluation (optional)

Use the information in the draft to calculate a_{hv} corrected for each operator. Then combine the results into one a value. Use the information in ISO 20643 to calculate the K value for the test performed.

A.7 Grinding vs. no-load-vibration lines (optional)

Three possible lines can be drawn from the raw data. This will be done for all test sites in the end of the round-robin test. Two lines can be calculated by each lab using the appendix in the draft and the test procedure described in A.8.

A.8 David Smeatham's method (optional)

A corrected emission value can be calculated using the information below.

The data can be converted to an estimate of the upper quartile vibration (eUQV) using the equation below:

$$\text{eUQV} = \text{slope} \times \text{free running vibration} + \text{intercept}$$

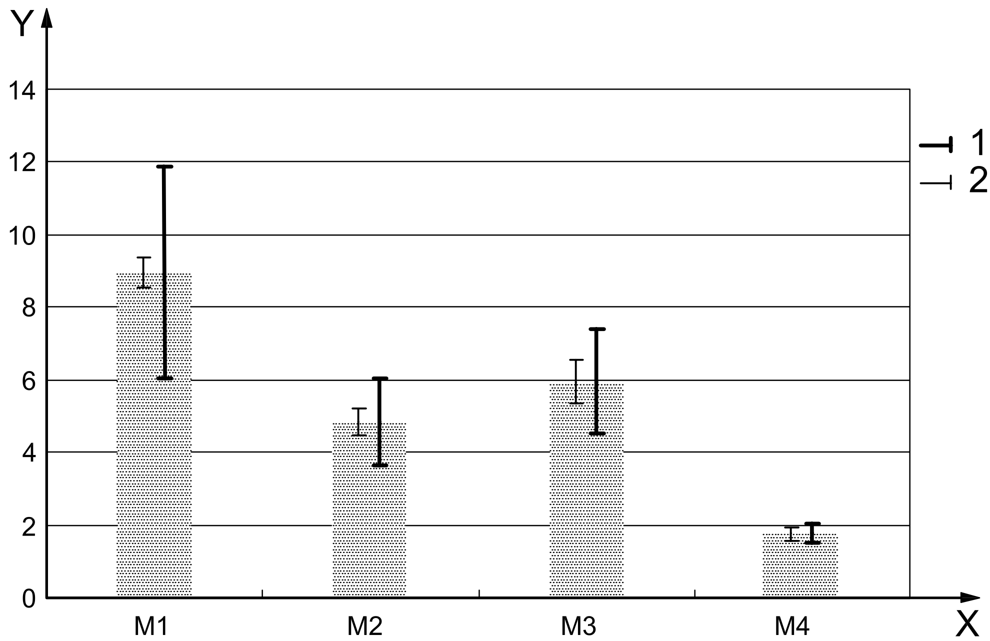
where “slope” is from a regression line drawn through the data points of a graph with free running vibration on the X-axis and grinding vibration on the Y-axis, “free running vibration” is the result of the tests using the aluminium wheel, and “intercept” is the point at which the regression line crosses the Y-axis.

Annex B
(informative)

Diagrams

B.1 Emission values and standard deviations

See Figures B.1 to B.13.



Key

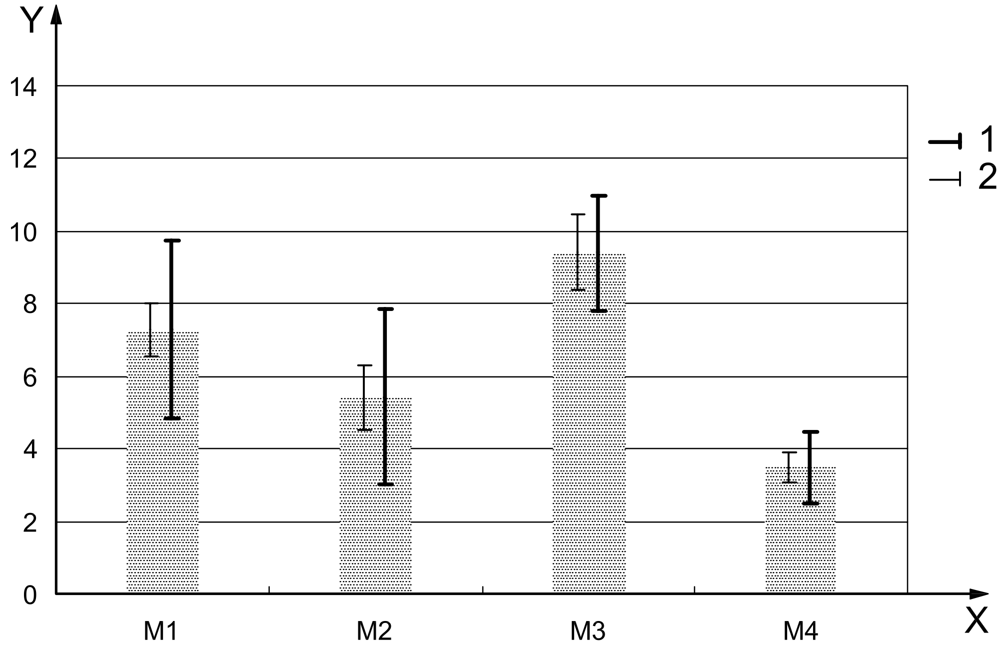
X grinder

Y a_h, m/s^2

1 spread, lab

2 spread, operator

Figure B.1 — No-load average and spread — All measurements — Maximum handle



Key

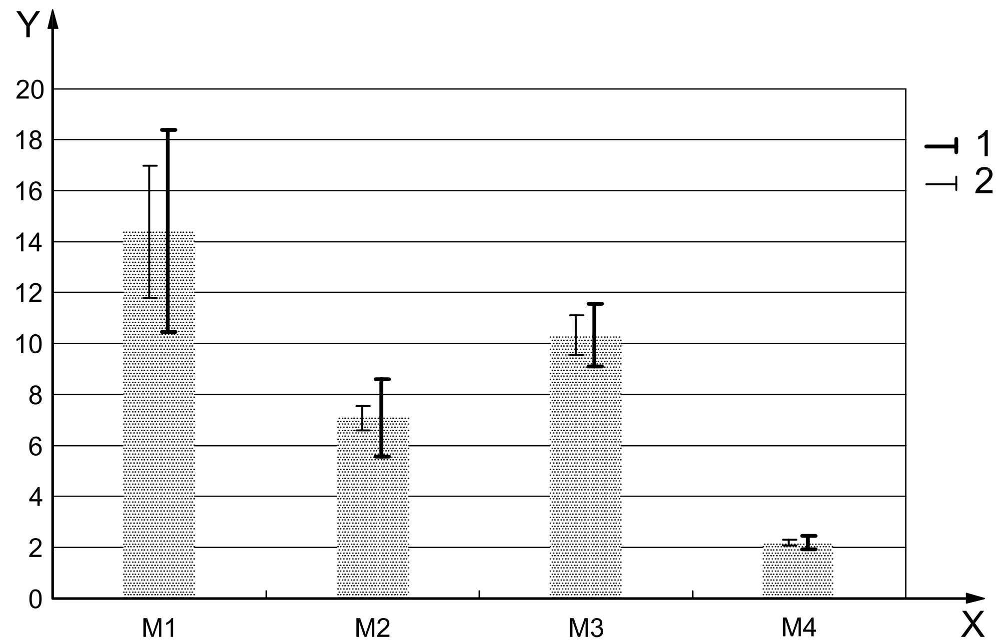
X grinder

Y a_h, m/s^2

1 spread, lab

2 spread, operator

Figure B.2 — Grinding average and spread — All measurements — Maximum handle



Key

X grinder

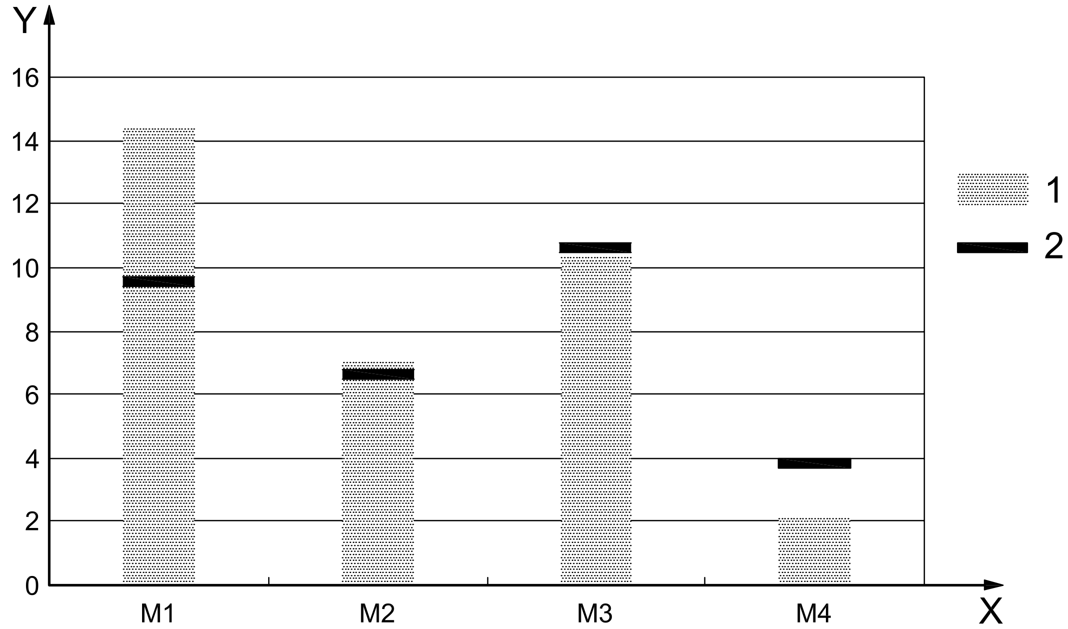
Y a_h, m/s^2

1 spread, lab

2 spread, operator

Figure B.3 — Unbalance disc average and spread — All measurements — Maximum handle

B.2 Unbalance disc test related to upper quartile for grinding



Key

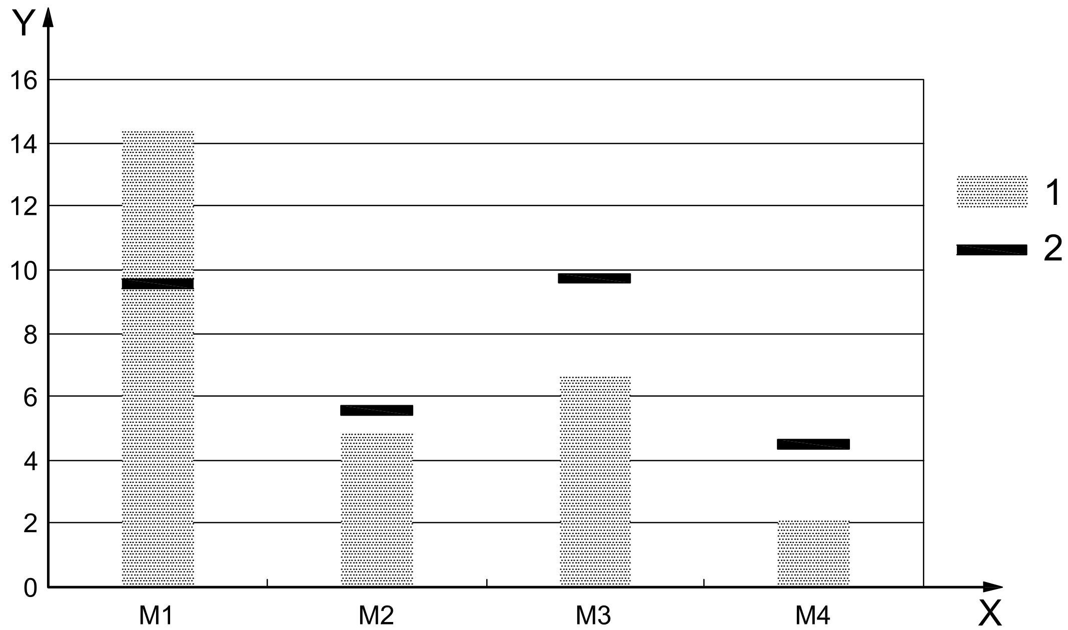
X grinder

Y a_h, m/s²

1 Al-disc

2 3rd quartile grinding

Figure B.4 — Unbalance disc test related to upper quartile for grinding — Maximum handle



Key

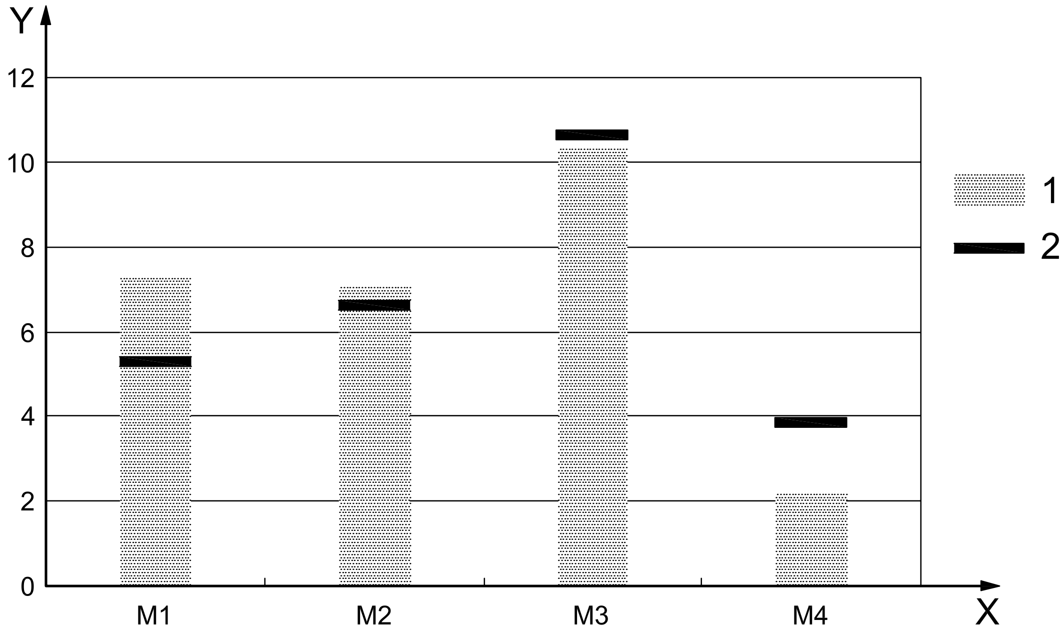
X grinder

Y a_h, m/s²

1 Al-disc

2 3rd quartile grinding

Figure B.5 — Unbalance disc test related to upper quartile for grinding — Support handle



Key

X grinder

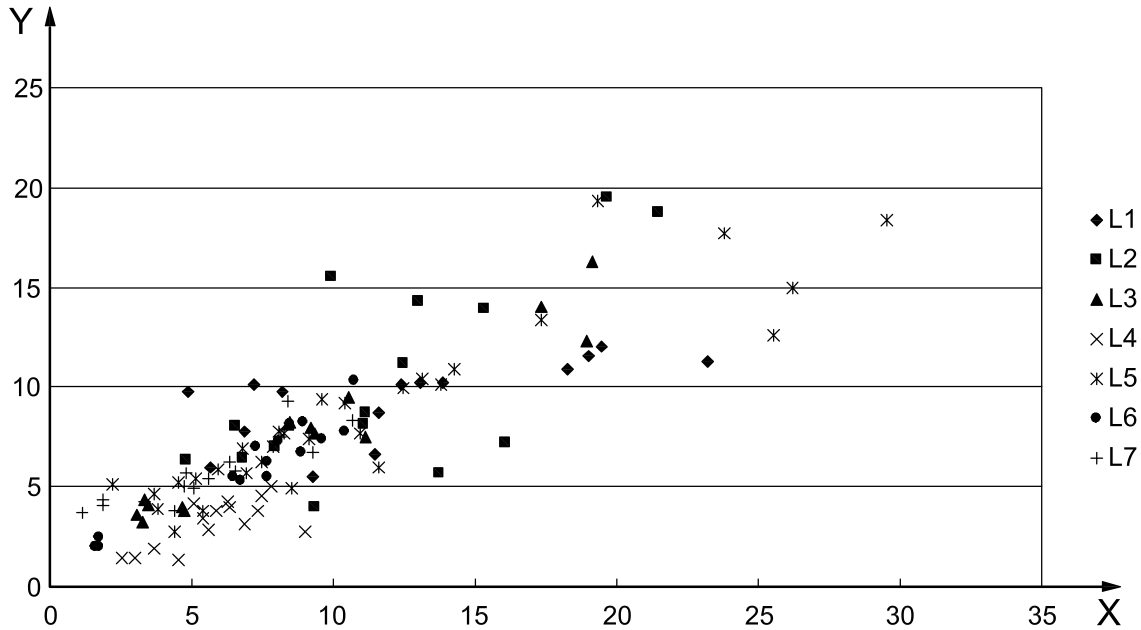
Y a_h, m/s^2

1 Al-disc

2 3rd quartile grinding

Figure B.6 — Unbalance disc test related to upper quartile for grinding — Throttle handle

B.3 Correlation between no-load and grinding vibration

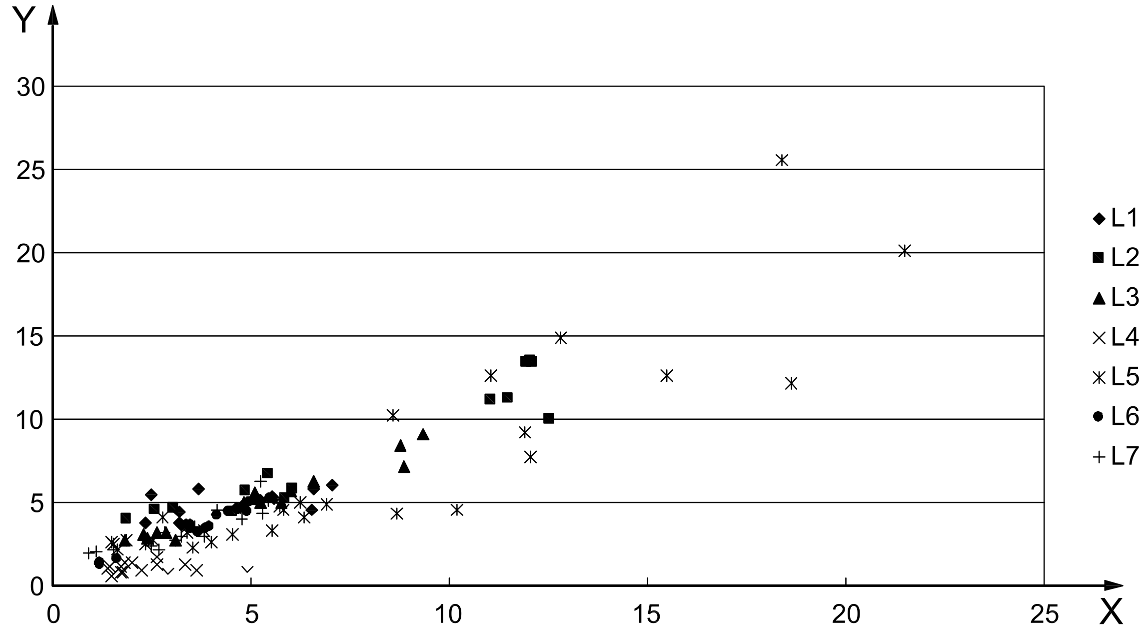


Key

X no-load vibration, a_{hv}, m/s^2

Y grinding vibration, a_{hv}, m/s^2

Figure B.7 — Correlation between no-load and grinding vibration — M1 support handle

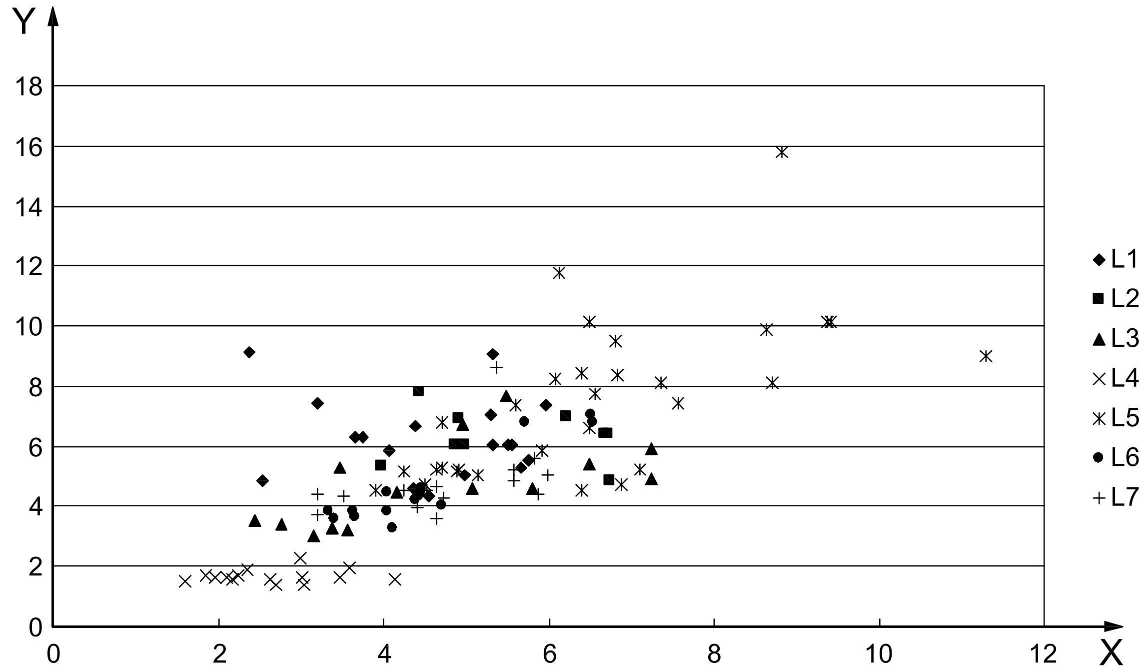


Key

X no-load vibration, a_{hv}, m/s^2

Y grinding vibration, a_{hv}, m/s^2

Figure B.8 — Correlation between no-load and grinding vibration — M1 throttle handle

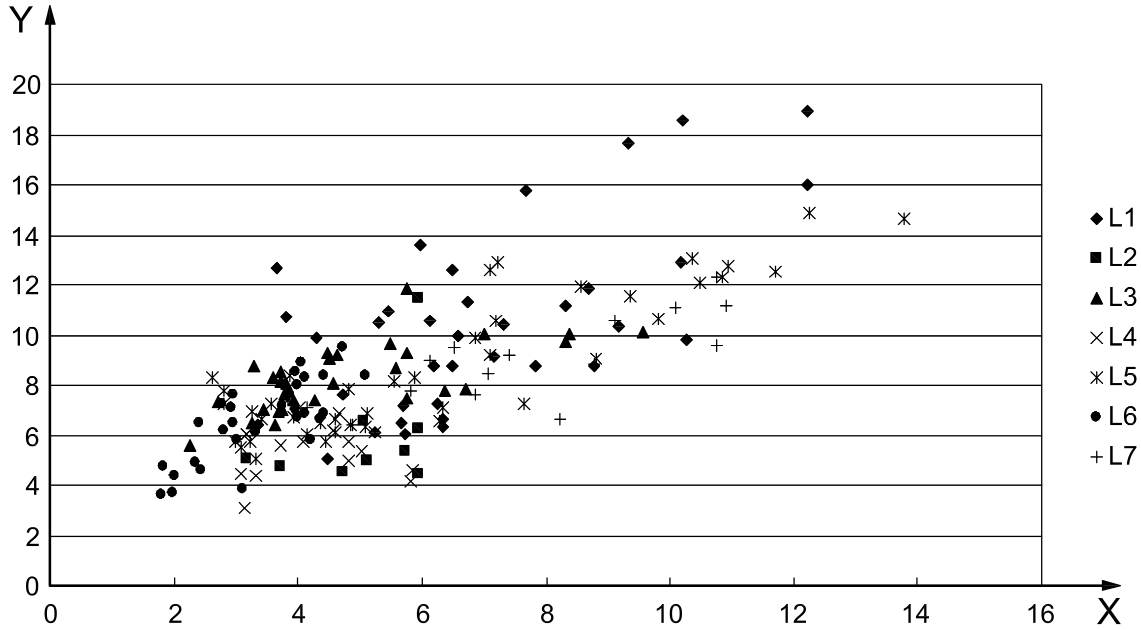


Key

X no-load vibration, a_{hv}, m/s^2

Y grinding vibration, a_{hv}, m/s^2

Figure B.9 — Correlation between no-load and grinding vibration — M2 Throttle handle

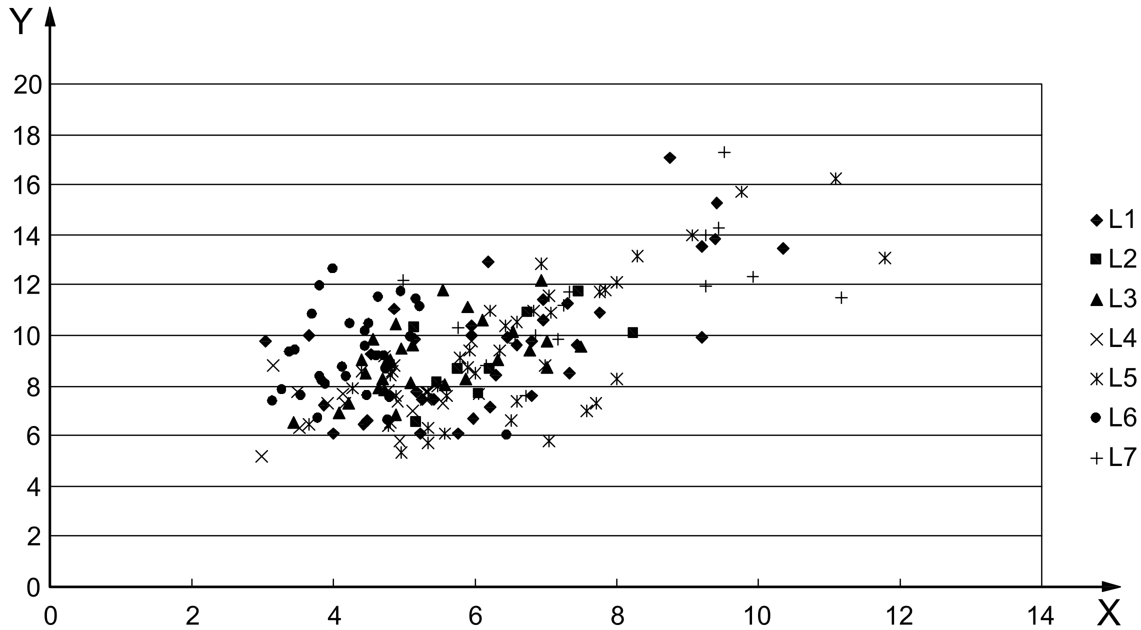


Key

X no-load vibration, a_{hv}, m/s^2

Y grinding vibration, a_{hv}, m/s^2

Figure B.10 — Correlation between no-load and grinding vibration — M3 support handle

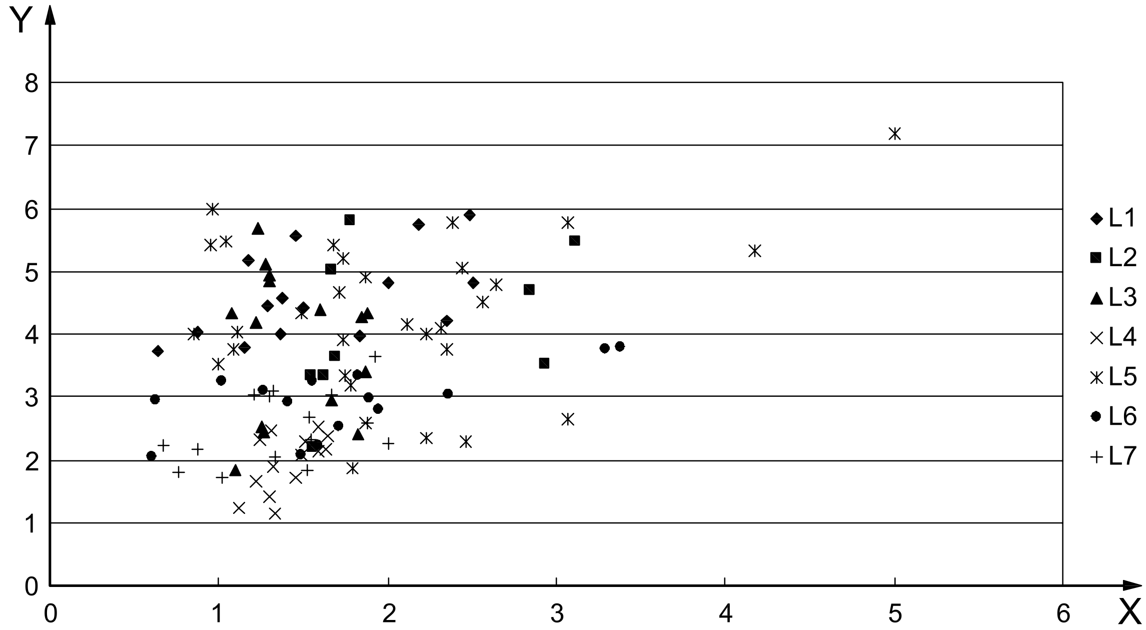


Key

X no-load vibration, a_{hv}, m/s^2

Y grinding vibration, a_{hv}, m/s^2

Figure B.11 — Correlation between no-load and grinding vibration — M3 throttle handle

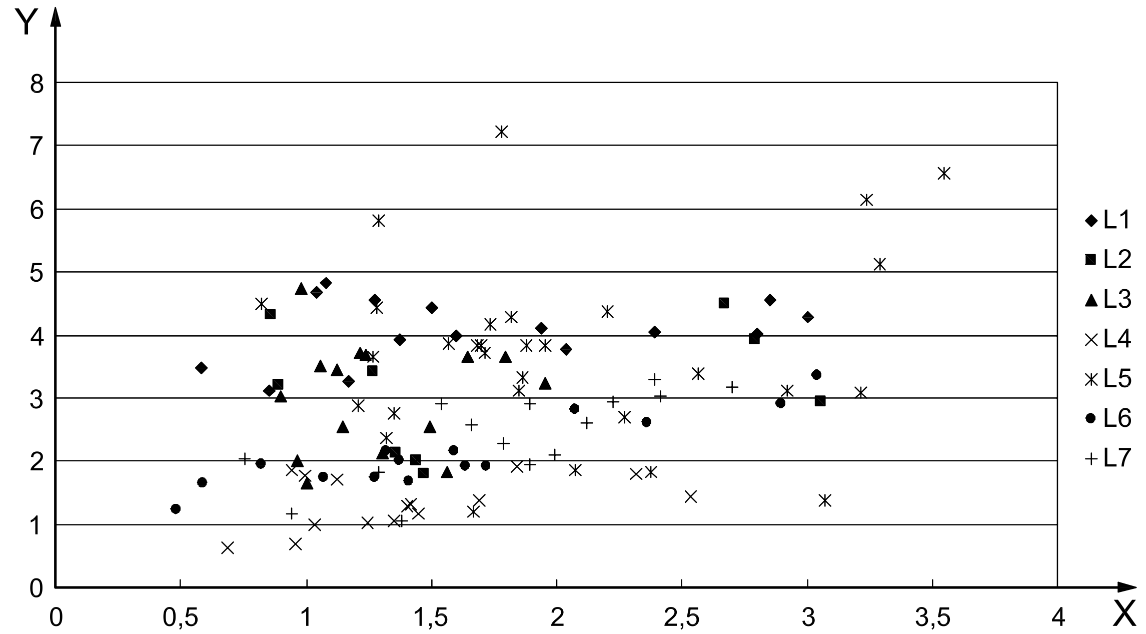


Key

X no-load vibration, a_{hv}, m/s^2

Y grinding vibration, a_{hv}, m/s^2

Figure B.12 — Correlation between no-load and grinding vibration — M4 support handle



Key

X no-load vibration, a_{hv}, m/s^2

Y grinding vibration, a_{hv}, m/s^2

Figure B.13 — Correlation between no-load and grinding vibration — M4 throttle handle

Annex C
(informative)

List of grinders and laboratories

C.1 Grinders [1)]

M1 George Renault KA 11 120 B5, pneumatic

M2 Atlas Copco AG 125 with Autobalancer, electric

M3 FLEX L 3206 C, electric

M4 AtlasCopco GTG40 with Autobalancer, pneumatic

C.2 Laboratories

L1 AtlasCopco Tools AB

L2 AtlasCopco Electric Tools

L3 Bosch

L4 Fachhochschule, Esslingen

L5 George Renault

L6 Health and Safety Laboratories, UK

L7 Berufgenossenschaftlisches Institut für Arbeitssicherheit

1) This information is given for the convenience of users of this Technical Report and does not constitute an endorsement by ISO of these products.

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