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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: $s_{op} = \sqrt{\frac{1}{n-1}\sum_i \sum_j \left(a_{i,j} - \bar{a}_i\right)}$ $a_{i,j}$ value for operator j at laboratory i $\bar{a}_i$ mean value for laboratory i	m/s^2
s_R	Standard deviation of reproducibility for laboratories according to EN 12096:1997, A.10: $s_R = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n} \left(a_i - \bar{a}\right)^2}$ a_i results achieved at n different laboratories $\bar{a}$ 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.

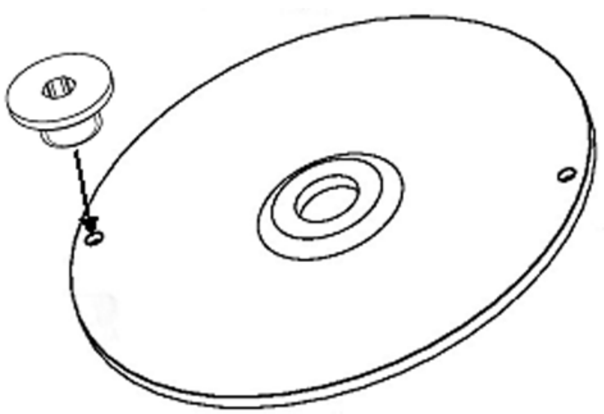

Figure 1 — Sketch of unbalance test disc (unbalance screw enlarged)

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/s²	s_{op} m/s²	s_R m/s²	a_h m/s²	s_{op} m/s²	s_R m/s²	a_h m/s²	s_{op} m/s²	s_R m/s²
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