Edinburgh, Scotland
EURONOISE 2009
October 26-28

Noise emission data for hand-held concrete breakers

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ABSTRACT

Standard tests have been developed in support of the EU Machinery Directive that define how noise emission values should be obtained for different machine or tool types. It can be difficult to design standard tests that are based on realistic operations and which also give repeatable and reproducible results. Standard tests are therefore commonly based on artificial operations. However there is concern that the resultant noise emission data may not reflect the noise generated by the tool during normal use.

Noise emission values were determined for a sample of new concrete breakers using the standard test defined in the Noise Emission in the Environment by Equipment for use Outdoors Regulations 2001. These sound power levels were then compared with the sound power levels generated by the same tools on a selection of work surfaces during simulated real-use tests.

The manufacturers' declared noise emission values could not be verified in the majority of cases, partly because of omissions and technical difficulties with the standard test method. The real-use sound power levels were 2 to 7 dB higher than the emission values determined by the Health and Safety Laboratory (HSL). This is probably because the standard test looks only at noise emitted by the breaker itself, and not noise generated by the machine/inserted tool/work surface interaction.

Although there were significant differences in declared noise emissions between some of the breakers, there were no significant differences between the real-use emission data. Therefore, using manufacturers' declared noise emissions as the basis of selecting/purchasing a concrete breaker will not reliably result in the selection of a tool that is low- or lower-noise in conditions of real-use.

1. INTRODUCTION

The EU Machinery Directive[1] places duties on machine manufacturers and suppliers to design and construct machinery in such a way that noise emissions are reduced to the lowest level taking account of technical progress and the availability of techniques for reducing noise, particularly at source. There is also a requirement that manufacturers and suppliers provide information on the airborne noise emissions of their products, to allow users to make informed choices regarding the safety of a potential purchase.

Standards have been developed in support of the EU Machinery Directive that define how noise emission values should be obtained for different machine types. Ideally these standard tests should provide noise emission data that is representative of the expected noise emission in normal use, allow tools of the same type to be compared, and identify low-noise tools thereby highlighting successful low-noise designs. In practice it can be difficult to design standard tests that are based on realistic operations and which give repeatable and reproducible results. It is common for standard tests to be based on artificial operations; however there is concern that the resultant standard noise emission

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data may not reflect the noise generated by the tool during normal use. There is a need therefore to evaluate the standard noise emission tests.

Hand-held concrete breakers are covered by both the EU Machinery Directive and the Noise Emission in the Environment by Equipment for use Outdoors Directive[2], implemented in the UK as the Noise Emission in the Environment by Equipment for use Outdoors Regulations 2001[3] (NEEEOR 2001). These regulations include the method for measuring airborne noise emissions for concrete breakers; they also require the manufacturer to declare a guaranteed sound power level that does not exceed the applicable permissible sound power level specified in the NEEEOR 2001. The guaranteed sound power level is defined as a sound power level that includes an allowance for uncertainties in the determination of sound power level due to production variation and measurement procedures.

The aims of the work reported here were:

- To assess the test method defined in the NEEEOR 2001 for usability and repeatability;
- To compare measured noise emission values with manufacturers' declared noise emission values;
- To compare the measured noise emission values with the noise generated by the same tools during simulated real-use tests; and,
- To establish whether declared noise emission data can be used as an indicator of noise hazard.

Throughout this paper the guaranteed noise emission data declared by the manufacturer and supplied with the concrete breaker is referred to as the *declared emission*. The noise emission measured by HSL in accordance with the requirements of the NEEEOR 2001 is referred to as the *measured emission*.

2. TOOLS TESTED

Six new breakers were obtained for testing; they are described in Table 1. All the tools were pneumatic and incorporated a silencer (muffler). All were fitted with anti-vibration handles except Tool B. The guaranteed sound power levels for the six tools tested were between 106 and 111 dB, ie the difference between the lowest and highest declared noise emission value was 5 dB.

Table 1: Tools obtained for testing.

Tool	Chuck size mm	Weight kg	Max pressure bar	Air consumption l/min	Impact frequency Hz	Guaranteed declared sound power level dB(A)
A	32 hex x 160	27.5	7	1920	23	109
B	32 hex x 160	24.5	7	1920	23	109
C	32 hex x 160	25	6	1250	23	107
D	32 hex x 160	32	6	1560	16	106 (*a*=105; *K*=1)
E	32 hex x 160	30.5	7	1700	20	111
F	25 hex x 108	21	7	1300	22	108

3. STANDARD NOISE EMISSION MEASUREMENTS

The NEEEOR 2001 cite basic noise measurement standards and general supplements to these standards, for both measuring sound pressure levels on a measurement surface enveloping the source and for using these sound pressure measurements to calculate the sound power level produced by the source. For concrete breakers the basic noise measurement standard is BS EN ISO 3744: 1995[4].

Simultaneous sound pressure level measurements were made at six defined points positioned on a hemisphere with radius 4 m according to the requirements of the NEEEOR 2001. Simultaneous measurements were made with microphones located at the six points. The output from the microphones was connected to a multi-channel real-time noise analyser. The sound pressure levels measured at each position were combined to give the A-weighted surface sound pressure level. The noise generated by the concrete breakers during the tests was steady; therefore the A-weighted surface sound pressure level was calculated from the energy average of the six measurements. The breakers were tested on a concreted area, therefore the calculations of sound power are those for a hemispherical surface of area $S=2\pi r^2$, enveloping the source and terminating on a reflecting plane.

Figure 1 shows the test rig used for obtaining noise emission data for concrete breakers. In accordance with the requirements of the NEEEOR 2001, it consisted of a tool embedded in a 0.6 m x 0.6 m x 0.6 m concrete block, which was placed in a concrete pit sunk into the ground. A concrete screening slab covered the block. During the emission tests, the breaker under test was coupled to the tool embedded in the concrete block. Compressed air was supplied to the breaker via an in-line regulator, which ensured the breaker was operated at the maximum working pressure specified in the instructions supplied with the tool.

Figure 1: NEEEOR 2001 standard test rig at HSL for concrete breakers.

To avoid parasitic noise (ie any noise at the measuring points generated by the breaker but not directly radiated by it), the concrete block was positioned on four anti-vibration mounts positioned in each of the four corners of the concrete pit. The cut off frequency of the mounts complied with the requirements of the NEEEOR 2001.

The method in the NEEEOR 2001 does not specify whether the breaker shall be operated with or without an operator during emission tests. This is a significant omission. Guidance was therefore taken from the previous standard test used to measured breaker noise emission values, which is specified in the EU concrete breaker directive 84/537/EEC[5]. In this test, "the breaker is run unattended by an operator in the manner described below:

- The breaker is operated in an upright position on the concrete block rig, which is fitted with a tool shank of the correct size for the breaker under test.
- The breaker is firmly held down by a flexible device in order to give the same stability as that existing under normal operating conditions, when the tool is embedded in the material that is to be broken up before it fractures; the flexible device may take the form of calibrated springs or pneumatic jacks, for example."

In the HSL test rig, the breakers were held in place with a pneumatic jack supported by a steel crossbeam as shown in Figure 2.

Figure 2: Set up for supporting breaker during noise emission tests.

4. SIMULATED REAL USE MEASUREMENTS

Simulated real use tests were carried out using the six concrete breakers described in Table 1 to obtain normal use sound power levels and sound pressure levels during realistic tasks. Three fully trained, experienced tool operators tested the breakers on concrete and tarmac surfaces. Tests were carried out using standard and vibration reduced steels; moil points were used on concrete and tarmac cutters on tarmac.

The test area was situated roughly in the centre of an array of six microphones located at the positions defined for the standard noise emission tests. The operators were instructed to break up the surface with the breakers as they would during normal use. Simultaneous noise measurements were made at each microphone position during these tests. This data was used to calculate the sound power level. The operator repeated the breaking task enabling (noise measurements to be made close to the ear using a sound level meter, as shown in Figure 3.

Figure 3: Noise measurements at the operator's ear.

5. RESULTS

Table 2 contains the results of the standard noise emission tests for six concrete breakers tested using the HSL standard test rig.

Table 2: HSL measured noise emission.

Tool	[a]Measured emission (L_1) dB(A)	[b]Declared emission (L_d) dB(A)	[c]Verified?
A	110	109	No
B	107	109	Yes
C	107	107	Yes
D	107	106	No
E	114	111	No
F	109	108	No

[a] Measured emission (sound power level) obtained using the arithmetic mean of the two highest A-weighted surface sound pressure levels;
[b] Declared single-number noise emission value $L_d = (a + K)$;
[c] Verification of the measured emission values is obtained by applying the criteria defined in BS EN ISO 4871[6] and EN 27574-2[7] ie is $L_1 \leqslant L_d$

Table 3 contains mean sound power levels and mean sound pressure levels measured for each of the breakers during simulated real tests. They were obtained for each breaker by combining all the data obtained for individual operators, different surfaces and different steels. These mean levels take into account all the variables that may affect the noise levels generated by a breaker, and were therefore considered a good estimate of noise levels during normal use.

Table 3: Mean sound power levels and mean sound pressure levels during simulated real use.

Tool	Sound power level dB(A)		Sound pressure level dB(A)	
	Mean	**Standard deviation**	**Mean**	**Standard deviation**
A	111.0	1.1	92.5	2.2
B	111.3	1.2	93.8	2.1
C	111.8	0.9	94.6	2.0
D	112.4	1.7	92.9	1.2
E	113.0	1.0	93.9	1.2
F	115.1	0.5	95.6	1.5

6. DISCUSSION

A. Comparison of declared and measured noise emission data

For a single tool (rather than a batch of tools), the manufacturer's declared emission is verified if the measured noise emission value, L_1 is less than or equal to the declared single-number or dual-number noise emission value[6,7].

The results in Table 2 show that HSL verified the manufacturer's declared noise emission for only two of the six breakers tested: Tool B and Tool C. Tool B was the only breaker tested that does not have anti-vibration handles. The largest difference between the declared and measured noise emission was for Tool E. However a fault with the breaker sleeve of Tool E meant it was possibly not a representative sample of this type of breaker.

B. Problems with the standard emission test specified in the NEEEOR 2001

Manufacturers' declared noise emissions could not be verified in the majority of cases. It was possible that this was due in part to difficulties with the standard test defined in the NEEEOR 2001. Omissions in the standard test and technical difficulties in meeting some of its requirements may result in differences between the noise emission data obtained by different test houses. The main difficulties are described briefly below:

- The NEEEOR 2001 contain no information on how the breaker should be supported during the noise emission tests, including whether or not an operator should operate the tool. Guidance was taken from Directive 84/537/EEC, however this lacks details on certain aspects of the test that may influence the measured noise levels (eg the vertical force applied to the breaker handles).

- Without previous experience of the test it was difficult to construct certain parts of the test rig using the information contained in the NEEEOR 2001; in particular the system of reinforcing rods within the concrete block, and the intermediate piece used to connect the breaker to the tool embedded in the concrete block.
- The NEEEOR 2001 require the concrete block to be insulated against the bottom and sides of the concrete pit with elastic blocks with a specified cut-off frequency. Although appropriate anti-vibration mounts fit into the bottom of the pit, there is insufficient space around the sides of the block to comply with this requirement.
- The test method in the NEEEOR 2001 contains several typographical errors, which hinder construction of the test rig.

C. Permissible sound power levels

One of the requirements of the NEEEOR 2001 is that the guaranteed sound power level of equipment does not exceed specified maximum permissible sound power levels. The NEEEOR 2001 were amended in 2005[8]; for concrete-breakers heavier than 15 kg and lighter than 30 kg the permissible sound power levels for Stage I (ie as from 3 January 2002) shall continue to apply for Stage II (ie as from 3 January 2006). This amendment in 2005 affects Tools D and E. Table 4 contains the permissible sound power levels and the manufacturer's declared emission for the breakers tested at HSL.

Table 4: Permissible sound power levels.

Tool	Permissible sound power level L_W dB		Declared emission		Measured emission	
	Stage I	Stage II	L_d dB(A)	Is L_d equal to or below L_W (Stage II)	L_1 dB(A)	Is L_1 equal to or below L_W (Stage II)
A	110	110	109	Yes	110	Yes
B	109	109	109	Yes	107	Yes
C	109	109	107	Yes	107	Yes
D	113	111	106	Yes	107	Yes
E	112	110	111	No	114	No
F	109	109	108	Yes	109	Yes

The results in Table 4 show that both the declared and measured emission values exceed the permissible sound power level only for Tool E. The consequence of this is that Tool E should not be placed on the market or put into service according to the requirements of Regulation 7 in the NEEEOR 2001. However as previously discussed, it is possible that the sample of Tool E tested here was not representative for this type of breaker.

D. Analysis of HSL measured noise emission

Before comparing the measured noise emission data obtained for the six breakers, it was necessary to establish whether the measured emission values for the different tools were significantly different from each other. Statistical analysis, using one-way analysis of variance (ANOVA) and the Tukey HSD test, performed on the measured emission data showed that Tools B, C and D were not significantly different at the 5% level of significance; they were therefore given the same rank.

E. Use of emission data to identify high noise and low noise breakers

Table 5 shows the results of ranking the breakers based on their emission values; 1 indicates the quietest breaker and 6 the noisiest breaker.

Table 5: Ranking of breakers based on declared and measured noise emission.

Tool	Declared emission	Declared emission rank	Measured emission	Measured emission rank
A	109	4.5	110	5
B	109	4.5	107	2
C	107	2	107	2
D	106	1	107	2
E	111	6	114	6
F	108	3	109	4

The Spearman r_s correlation coefficient was calculated from the ranked data in Table 5 to investigate the relationship between the declared and measured noise emission data. At the 5% significance level, the correlation was not significant. However, when the data for Tool B was excluded, the correlation between the two sets of data was significant. This shows that for breakers fitted with anti-vibration handles, the standard test produces noise emission data that is reproducible. The results for Tool B suggest further work is needed to investigate the method used to obtain noise emission data for tools with fixed handles. Although the declared and measured emission values did not rank the tools in exactly the same order, they did both identify Tool D as one of the quietest breakers and Tool E as the noisiest breaker.

All the breakers tested were fitted with silencers, which enclosed the main body of the tool. According to one tool manufacturer most silencers share the same design although there may be differences in the quality of the materials used to make the silencer. The information provided with the breakers contained no details of design features intended to reduce tool noise. The manufacturer of Tool D, which was one of the quietest breakers, described using a tappet bush that has been effective at reducing noise and has a long life.

7. SIMULATED REAL USE NOISE DATA

The simulated real use test on tarmac involved working an open face by cutting along the tarmac surface to break it up. This task is typical of how the breaker is used in practice. The test on concrete was less realistic; it consisted of breaking out the concrete to a depth of approximately 5 cm then moving the breaker 8-10 cm to the side to start another break out. One operator used two of the tools to break up a concrete edge, which is a more realistic operation. The noise levels generated at the operator's ear during this more realistic task were up to 3 dB higher than those generated during the simulated real use test.

It is likely that the breakers will generate a range of different noise levels during normal use depending on many factors including the task, method of operation and type of surface. The purpose of the simulated real use tests reported here is to give an indication of the effect of surface type and steel type on different breakers under controlled conditions.

A. Effect of different surfaces

The breakers were tested on concrete and tarmac surfaces. The test results did not show a clear relationship between surface type and the noise levels generated. Statistical analysis using the related t-test suggested that choosing a heavier tool for concrete and a lighter tool for tarmac is likely to result in lower noise levels at the operator's ear.

B. Effect of different steels

One of the aims of the project was to investigate the methods used to reduce the noise generated by concrete breakers during normal use. The breakers were tested with standard and vibration-reduced steels. Statistical analysis using the related t-test suggested that vibration-reduced steels could make a significant difference when used with heavier tools. However there is insufficient data to explain why the vibration-reduced steels appear to reduce the sound power levels but increase the sound pressure levels, and also why they have different effects when used on different surfaces.

C. Ergonomic assessment of the tools

A questionnaire was administered to the operators following each breaker test to collect subjective information on productivity, comfort and ease of use[9]. The operators' comments showed that they did not like Tool C; they reported that this breaker "bounced around" on the surface and was unproductive. The operators preferred Tool E because it had good handles, was the right weight and was productive. When asked to comment on whether the vibration-reduced steels affected productivity, the operators' comments were inconclusive and dependent on the surface being broken.

D. Comparison of emission and simulated real use data

Measured noise emission values and simulated real use sound power levels and sound pressure levels for each breaker are shown in Figure 4. The mean simulated real use sound power levels are shown by yellow triangles, the mean simulated real use sound pressure levels by red circles; the error bars indicate the standard deviations, which were less than 2 dB for all of the breakers tested. *Note: In Figure 4 Lw denotes sound power level; Lp denotes sound pressure level.*

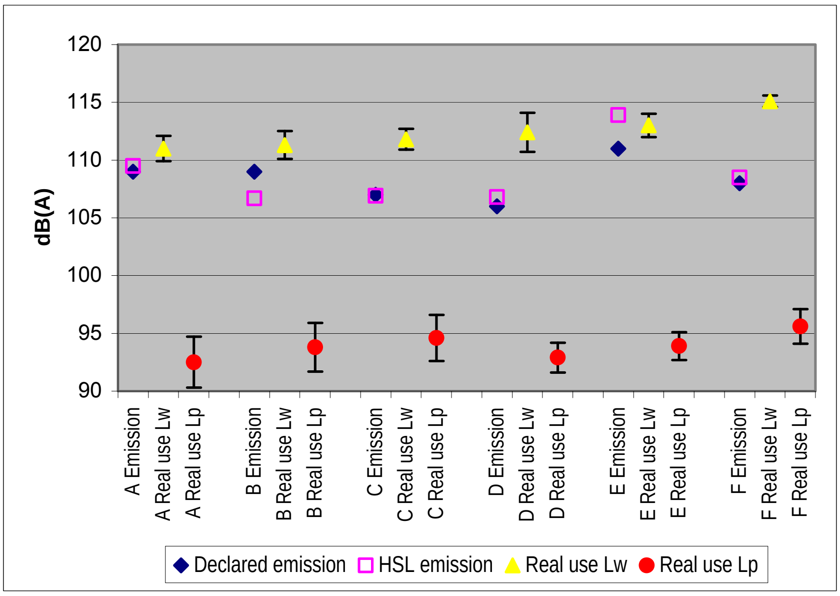

Figure 4: Emission and mean simulated real use noise levels.
NOTE: The declared emission values and HSL emission values are sound power levels.

The mean simulated real use sound power levels were generally between 2 and 7 dB higher than the measured noise emission values; the mean difference was 5 dB. Statistical analysis, using one-way analysis of variance (ANOVA) and the Tukey HSD test, performed on the simulated real use emission data showed that at the 5% level there was no significant difference between the sound pressure levels or the sound power levels generated by the different breakers during simulated real use.

Statistical analysis using the Pearson Moment Correlation Coefficient r showed that there was no significant correlation between the measured noise emission values and the simulated real use sound power levels and sound pressure levels for the breakers. The results presented here show that although the standard test produces noise emission data that are reproducible, it cannot indicate the relative noise hazard associated with different tools during normal use because the noise levels they generate are not significantly different.

One of the aims of the work reported here was to investigate whether emission data can be used to assess noise exposure of breakers during normal use. To do this, two sets of data were determined:

- The difference between the HSL measured noise emission values and the sound power levels generated during simulated real use tests (blue diamonds in Figure 5); and,
- The difference between the sound pressure levels at the operator's ear measured during standard emission tests and during simulated real use tests (pink squares in Figure 5).

In Figure 5 values less than zero indicate that the emission values underestimate the normal use noise levels; values greater than zero indicate that the emission values overestimate the normal use noise levels. Figure 5 shows that the measured noise emission values underestimated the sound power levels generated during simulated real use tests for Tools A, B, C, D and F. It is likely that this occurred due to the additional noise generated by interaction of the steel and the surface during the breaking process. The sound pressure levels measured at the operator's position during the standard tests were either comparable with or overestimated the sound pressure levels generated during simulated real use tests for all the breakers except Tool F. The sound power level takes account of the noise radiated from the breaker in all directions. In practice the sound pressure level measured at the operator's ear will depend on many factors including the directivity of the breaker noise and the position of the operator, for example relative to the breaker exhaust.

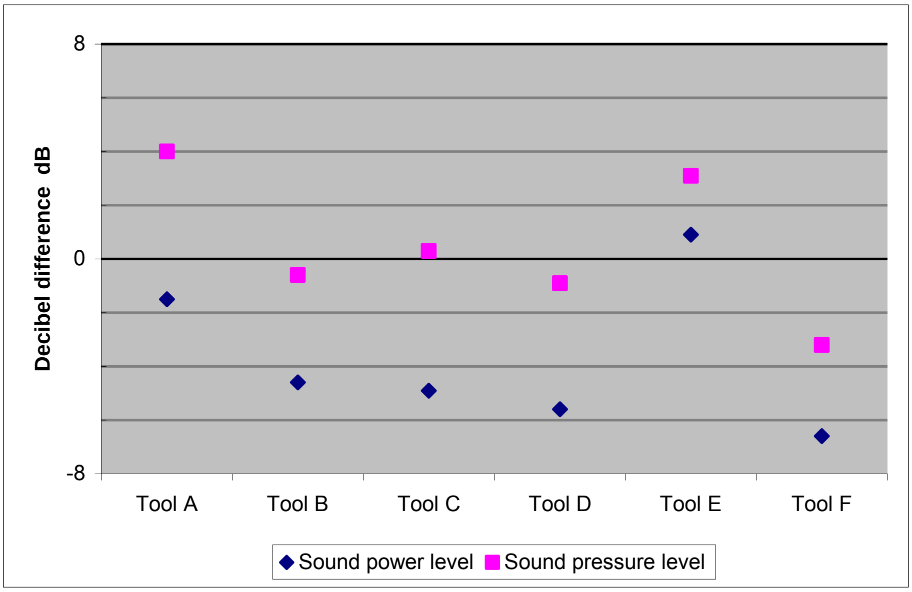

Figure 5: Difference between measured emission values and simulated real use noise levels.

8. CONCLUSIONS

Manufacturers' declared noise emissions could not be verified in the majority of cases. It is possible that this may be due in part to differing interpretations of the defined test method. Omissions and technical difficulties in the standard test method defined in the NEEEOR 2001 have been identified.

The noise emission data for the majority of breakers tested did not exceed the maximum permissible sound power levels specified in the NEEEOR 2001 when tested with the standard test method.

In real use the noise emission of the breakers was found to be higher, by factors between 1.5 and 5, than the noise emission obtained during standard tests. This is probably because the standard test method looks only at noise generated by the breaker itself, and not noise generated by the breaker/inserted tool/work surface interaction. The noise emission during real use tended to exceed the maximum permissible sound power levels.

When tested using the standard test method defined in the NEEEOR 2001, there were significant differences between the measured noise emission data for some of the breakers. However the breakers generated largely similar noise levels (sound pressure levels and sound power levels) during the simulated real use tests. The measured emission values are therefore not indicative of the relative noise hazard associated with each of the individual breakers during normal use.

In general, using manufacturers' declared noise emission values as the basis of selecting or purchasing a concrete breaker will not reliably result in the selection of a machine that is low- or lower-noise in conditions of real use.

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