

Elaboration of a standard procedure for the measurement of vibration emitted by percussive tools – Application to breakers

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BITSCH J, DONATI P, POIROT R, ROURE L. Elaboration of a standard procedure for the measurement of vibration emitted by percussive tools — Application to breakers. *Scand J Work Environ Health* 12 (1986) 347–350. The Association Française de Normalisation (AFNOR) is preparing a standard on the exposure assessment of vibration from percussive tools. Therefore, a test code was developed for the measurement of vibration from percussive tools under laboratory conditions. The handle vibration from six different breakers, among which three tools were of “antivibration design,” was measured with the following energy absorption methods: hydraulic base, steel shot, actual breaking of concrete, AFNOR concrete block, pointed chisel embedded in concrete. The last four methods were applied with breakers held by three successive operators. In addition, the first two were used with tools mounted in a rig which held them vertically and loaded them with a vertical downforce. The results indicated that the steel shot method was preferable although it gave 20 % lower vibration results than those recorded for the actual breaking of concrete. It has the advantages of yielding consistent results with low scatter and being simple and cheap. Since difficulties have been experienced during the use of a pneumatic rig with breakers of antivibration design conception, the shot method should be applied with human operators.

Key terms: breakers of “antivibration design,” energy absorption in methods, fidelity of results.

Habitual use of many vibrating hand-held tools (eg, breakers and chipping hammers, grinders, and chain saws) has been found to be associated with an incidence of various disorders affecting the blood vessels, nerves, bones, joints, muscles, or connective tissues of the hands and forearms.

This consideration leads to emphasis on the need for standardized vibration limits for specific tools. However vibration limits are of limited value unless they are supported by satisfactory standardized measurement procedures which may facilitate (i) the comparison between the overall vibration level transmitted to the hand-arm system and a maximum vibration limit, (ii) the comparison between vibration from different tools of the same type used under representative work conditions, and (iii) the determination of the degree of vibration reduction necessary to prevent severe exposure.

The purpose of this paper was to describe the development of a standardized method for measuring the vibration of percussive hand-held tools weighing more than 3.5 kg. This standard is being published by the Association Française de Normalisation (AFNOR) (NF E 90-322) (2). The standard is based upon measurement of vibration in chipping hammers and breakers initiated by the European Committee of Manufacturers of Compressors, Vacuum Pumps and Pneumatic Tools (PNEUROP) and original work on breakers carried out by the Institut National de Recherche et de Sécurité

(INRS) in cooperation with the manufacturers Maco-Meudon and Montabert. This report presents the new French standard NF E 90—322, compares alternative energy absorption methods in the case of breakers, and describes the procedure adopted to take into account the scatter of the values from measurement to measurement.

Measurement of vibration

The primary quantity used to describe the severity of vibration transmitted to the upper limb is the equivalent acceleration (a_{eqh}) which is defined as (1):

$$a_{eqh} = [a_{wx}^2 + a_{wy}^2 + a_{wz}^2]^{1/2},$$

where a_{wx} , y or z is the frequency-weighted root-mean-square (rms) acceleration (4) in meters per square second simultaneously measured on one or both handles within the bandwidth 8 to 250 Hz, in each of the three perpendicular directions.

Figure 1 shows the correct way to mount the accelerometer on the tool. The weight of the accelerometer mount block, including the screws and collars, has to be less than 120 g.

Operating conditions

A suitable test code under which vibration measurements are made must satisfy the following conditions: (i) it must give representative values of vibration; (ii) it must achieve repeatable and reproducible results (fidelity); and (iii) in addition, it must be practical, simple, and cheap.

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These different requirements are generally difficult to attain simultaneously. Compromise solutions (particularly the choice of operating conditions) have to be found for each type of tool. Therefore tests simulating real conditions are sometimes used to reduce the scatter of the results. The values thus obtained are of course less realistic than when vibration is measured during actual handling of the machine in an industrial operation.

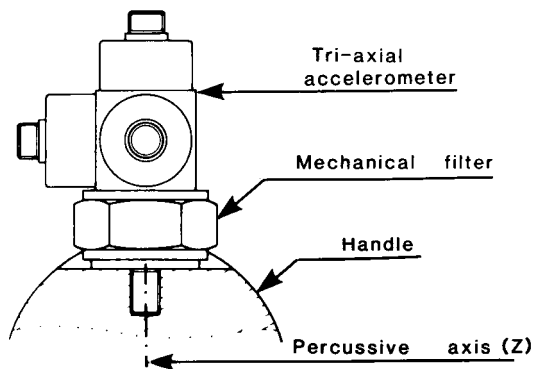


Figure 1. Accelerometer mounting for percussive tool handles.

Category of percussive machines

Percussive hand-held machines can be divided into the following three main types (2):

Category A: those with the tool rigidly fixed to the piston (eg, rammers, tamping tools).

Category B: those with the tool independent of the piston (eg, breakers) and used in road work and mining.

Category C: those with the tool independent of the piston (eg, chipping hammer) and used in metal working.

For machines in category A measurements should be carried out with a properly serviced hammer, together with the most representative tool for this type of machine. The operator should ram fine-wetted sand contained in a metal box which should allow for a working radius of at least 0.3 m for rammers and 0.5 m for other tools. The depth of the sand must be at least 0.2 m. (See figure 2.) For category C the work conditions recommended are similar to those proposed by PNEUROP (3). The measurements should be carried out with a properly serviced chipping hammer together with a chisel correctly sharpened. In addition the operator should chip, on a fixed mounted piece

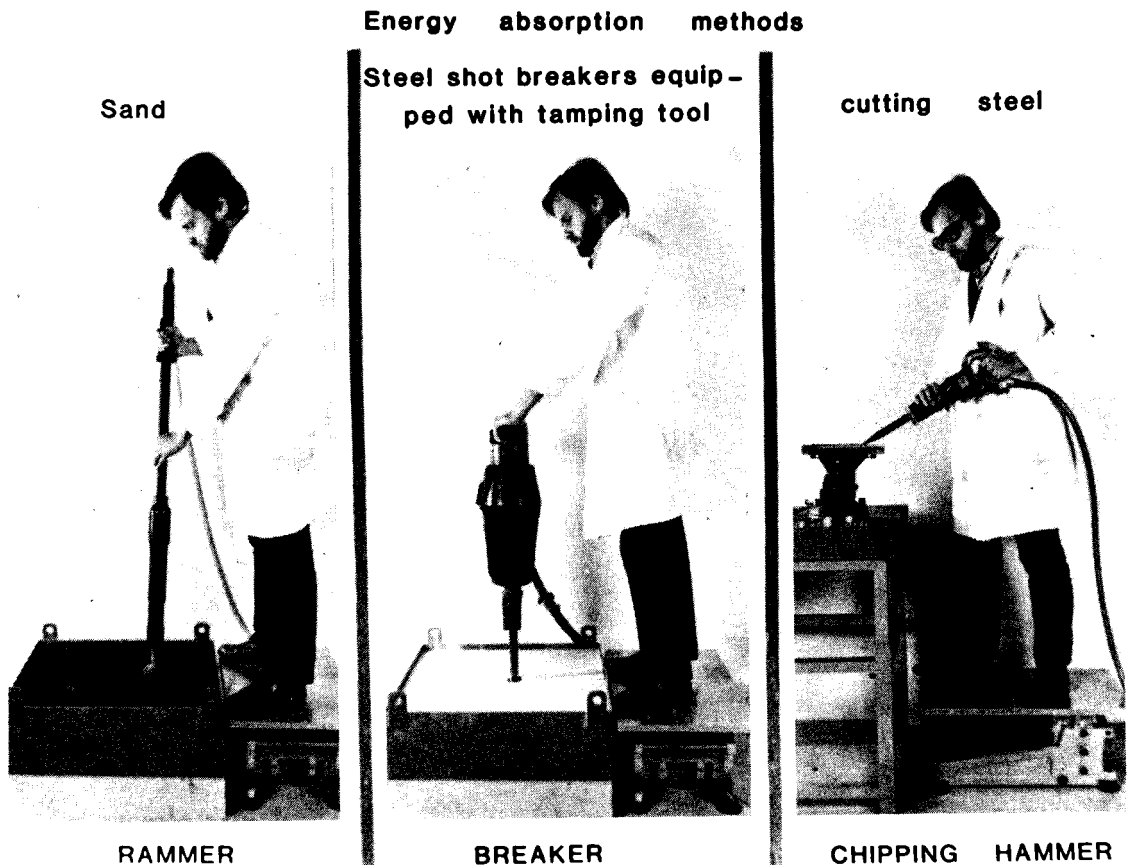


Figure 2. Operating conditions used for each category of tools (Operator stands on a scale measuring the downforce applied.)

of mild steel, and remove a uniform layer of approximately 2 mm in thickness. (See figure 2.) Measurements for category B are discussed in the following section.

Category B

Comparison of different energy absorption methods.

Different possible energy absorption methods can be used for machines in category B: steel shot with a rig as proposed by PNEUROP, hydraulic blow absorption base with a human operator or a rig, use of the AFNOR block with a human operator as proposed for the noise test of the European Economic Communities, or a pointed chisel embedded in a stone or concrete block with a human operator.

A preliminary series of tests was made with a Chicago Pneumatic (CP) breaker, type 1230 S, in order to compare the values of the vibration measured with the aforementioned methods with that obtained when concrete was actually broke. The scatter of the results was also assessed.

One handle of the breaker was equipped with a tri-axial Brüel & Kjaer (B & K) 4340 accelerometer mounted on a B & K UA 0559 mechanical filter and connected to an Endevco 2240 charge amplifier. At least three runs were conducted for each absorption method, the duration of each run being longer than 12 s.

The results showed that the different methods tested were all valid, and none could be discarded. The vibration characteristics (magnitude and frequency distribution) were comparable to those obtained when real concrete was broken (figure 3) although the values of the equivalent acceleration were lower and had a lower scatter.

In addition, a round robin test was organized by PNEUROP between five different laboratories to test the steel shot method. The same CP breaker was used with a downforce of 200 N applied by a hydraulic rig. The agreement was good between the different test stations since the weighted values obtained ranged from 13.7 to 19.8 m/s^2 .

Choice of an energy absorption method. A second series of tests was conducted with five different breakers, among which three tools were of "antivibration design," in order to check whether the methods described in the previous section accommodate breakers of all types (particularly those of antivibration design) and also to select a preferred method of measurement.

In an effort to minimize the number of tests to be made, the different energy absorption procedures were ranked in order of ascending difficulty and cost as follows: chisel embedded in a concrete block with operator, steel shot with rig or operator, hydraulic blow absorption with rig or operator, use of the AFNOR block with operator, free breaking of concrete.

The five breakers were equipped similarly to those used in the previous series of tests.

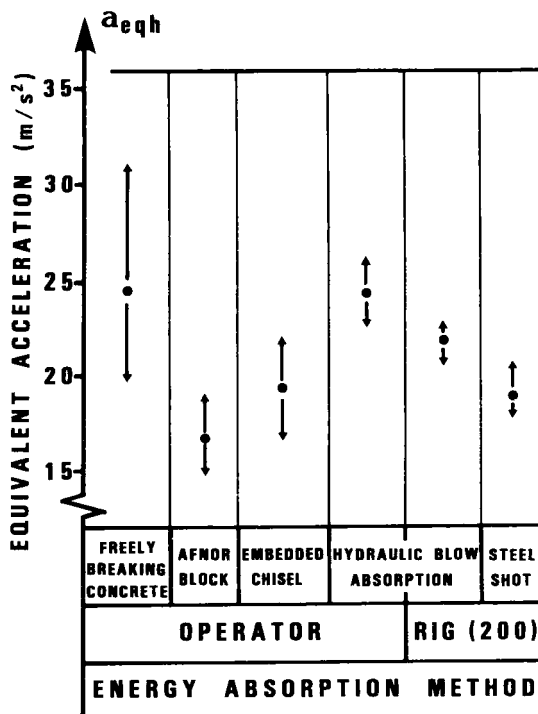


Figure 3. Values ($\bullet$ = mean, $\leftrightarrow$ = 100 %) of equivalent acceleration for the Chicago Pneumatic breaker type 1230 S according to the energy absorption method used. The time of linear integration for each run was at least 10 s.

The first method was quickly abandoned because of the existing possibility for the operator to reduce the level of vibration greatly by simply applying a low torque between the body and embedded chisel and because of the necessity to embed the chisel before each run.

Difficulties were experienced when the PNEUROP steel-shot method was applied using a pneumatic rig to hold breakers of antivibration design. The problem resulted from the fact that the reduced vibrating properties are based on the cushioning effect of spring-mass systems, which are adapted to the dynamic behavior of the hand-arm system. Therefore the shot method was also tested with three different operators instead of a rig, as proposed by PNEUROP. This approach proved satisfactory and yielded consistent results (figure 4). The other procedures were therefore not tested.

With the steel-shot energy absorption method measurements should be carried out with the use of a properly serviced machine and a tamping tool with specifications (diameter and thickness) dependent on the hammer weight to be tested. The machine should be held vertically by the operator so that the tamping tool can act in a box of 0.6-mm steel shot. (See figure 2.) The box diameter should be at least 500 mm, and the depth of shot 300 mm.

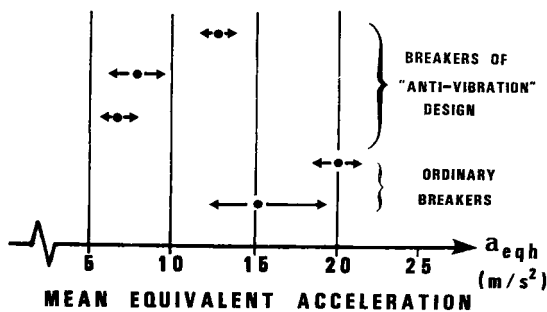


Figure 4. Values (• = mean, ← = 100 %) of equivalent acceleration for the five breakers measured with the steel shot method with three different operators (four runs per operator).

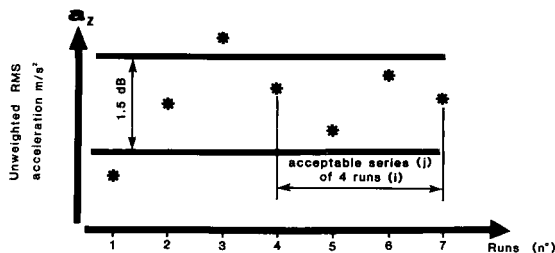


Figure 5. Conditions for repeatability. (RMS = root mean square)

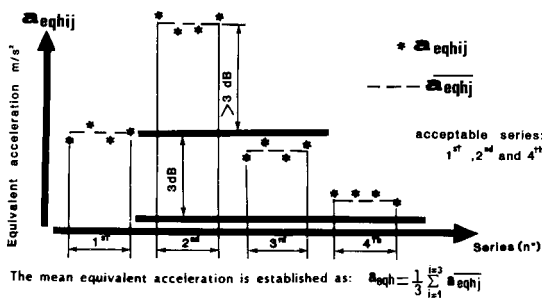


Figure 6. Conditions for reproducibility.

Fidelity of the results

Because of the difficulty in controlling all the extraneous variables, the vibration levels obtained varied from measurement to measurement even though the method of operation, the machine, and the tool were the same. Therefore AFNOR standard NF E 90-322 distinguishes between repeatability with the same operator from reproducibility when related to several operators.

To be acceptable according to the standard, vibration measurements must satisfy the following conditions:

REPEATABILITY: for each operator, runs must be repeated in order to obtain four consecutive results, called an acceptable series, so that:

$$20 \log \left[\frac{a_{z \max}}{a_{z \min}} \right] \leq 1.5 \text{ dB},$$

where a_z is the unweighted rms acceleration value along the percussive axis. (See figure 5.) For each acceptable series, it is necessary to calculate:

$$a_{eqhj} = \frac{1}{4} \sum_{i=1}^4 a_{eqhij}$$

where a_{eqhij} is the equivalent acceleration related to series j and run i .

REPRODUCIBILITY: Three acceptable series must be obtained with three different operators, such as (figure 6):

$$20 \log \left[\frac{a_{eqhj \max}}{a_{eqhj \min}} \right] \leq 3 \text{ dB}.$$

The mean equivalent acceleration is established as:

$$a_{eqh} = \frac{1}{3} \sum_{j=1}^3 a_{eqhj}.$$

Conclusions

A test code for the measurement of vibration from percussive tools under laboratory conditions has been developed at INRS. It gives representative values for vibration, yields repeatable and reproducible results, and is simple and cheap.

Percussive tools were divided into three main groups according to the operating task. Operators are required to ram fine-wetted sand with rammers and tamping tools, to tamp 0.6-mm steel shot with breakers, and to chip a uniform layer of 2 mm in thickness from a piece of mild steel with chipping hammers.

The test code has been applied to five different breakers, among which three were of antivibration design. The results show a significant difference between the two types (unsuspended and suspended). The difference between the equivalent acceleration for both categories is within 12 to 15 m/s². (See figure 4.)

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