Uncertainty measurement of sound levels for an essentially free field over a reflecting plane during cutting by a portable saw

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ABSTRACT

In the quest to contribute to the improvement in the tests of noise pollution from construction industries, the present study analyzes the uncertainty of measuring sound pressure for an essentially free field in a reflective plane during cutting by a portable saw, which is an electric cutter commonly used in industry (masonry saw). The methodology compares noise generated during shearing with that of non-cutting free-running equipment in accordance with ISO 3744:2010, which specifies methods for determining the sound power levels of noise sources by measuring the sound pressure for an essentially free plane. The study proposes sources of uncertainties and magnitudes associated with the instability of the operation, environmental conditions, assembly and tests in the determination of sound pressure for an essentially free field over a reflecting plane during cutting by a masonry saw. The diagrams identify the sources of uncertainties and input quantities that define the uncertainty of parameters and deviations. The expanded measurement uncertainty was evaluated under different load conditions in saw operations and the method adopted in this study is associated with a degree of precision 2 (in relation to the standard deviation of reproducibility) and is unstable in relation to the conditions of assembly and operation. In addition to identifying the relevant parameters and uncertainties of measurement with the masonry saw, these standardized assessments could help in the development of quieter machines as well as less disturbing and safer industrial practices.

Key words: Uncertainty measurement, noise measurement, ISO 3744, masonry saw, portable saw.

INTRODUCTION

The World Health Organization identify that Noise is the physical agent that constitutes one of the greatest potential risks to workers’ health in industry (WHO, 2011). Noise from construction is imputed as a contributor to illness and is treated as a public health issue (Stephenson, 2013; Brazilian Association of Technical Standards, 2010). Research in the United States on the prevention of occupational hearing loss stresses the importance of research and prevention (Stephenson, 2013). The health and safety of workers and the quality of life of those near industrial works are being considered increasingly important. Noise has been shown to increase blood pressure, cause stress reactions, and increase the risks of myocardial infarctions and strokes (Sjöström et al., 2013). Construction noise, which is particularly annoying to society, has significant contributions from machines and tools (Ballesteros et al., 2010). The World Health Organization recognizes noise pollution as the third most prevalent type of pollution after air and water pollution (WHO, 2011). The construction industry and its various machines and tools are significant noise makers. The United States Institute for Occupational Safety and Health states that about 90% of United States building workers are exposed to noise levels greater than 85 dB (A) (NIOSH, 2013). Builders seek new
processes to reduce the time and labor costs of their work. However, mechanized construction is noisy, with the most powerful equipment often being the loudest (Seixas et al., 2012). Hand-held electrical equipment is versatile and precise; there is a diverse range of such tools, and they are often inexpensive. They are widely used throughout construction, from infrastructure to finishing and repairs, and the portable saw is a common example (Barbosa and Bertoli, 2017).

A full assessment of the noise conditions in a loud environment requires knowledge of the noise generated by each particular source. Equipment manufacturers usually provide values of the sound pressure levels measured at a set distance from their equipment. The sound pressure level depends on the conditions of the propagating sound, including the presence of obstacles. Various environmental factors can influence the spread of sound, such as temperature, pressure, and relative humidity. Besides the directivity and source position, the material being worked with can also affect the noise associated with certain equipment. The assessment of both ambient noise and noise from specific pieces of equipment at construction sites is important to the development of quieter practices. Masonry saws are louder when cutting materials than when running freely (Barbosa and Bertoli, 2017).

ISO 3744:210 specifies methods for determining the sound power level of a noise source from sound pressure levels measured on a surface enveloping the noise source (machinery or equipment) in an environment that approximates an acoustic free field near one or more reflecting planes. Information is given on the uncertainty of the sound power levels and sound energy levels determined in accordance with this International Standard, for measurements made in limited bands of frequency. The uncertainty conforms to ISO 12001:1996, accuracy grade 2 (engineering grade) (International Organization for Standardization, 2010).

This article shows an expanded measurement uncertainty to be considered in a sound power method by portable saw operations according to ISO 3744:2010 and proposes parameters and deviations which define the uncertainties associated with the instability of the operation, environmental conditions, assembly and tests in the determination of sound pressure for an essentially free field over a reflecting plane, as part of efforts to identify sources of noise pollution from construction sites.

Characteristics of masonry saws and diamond abrasive blades

**Masonry saws**

Masonry saws cut stone, concrete, masonry, ceramics, and glass. They are hand-held and portable. The average power of the motor is 1,400 W and the removable diamond disk rotates at approximately 12,000 rpm. They can cut wet or dry, straight or at angles, and are widely used for minor cuts and floor finishing for tiles, bricks, and wood. Such saws are versatile, practical and ergonomic (International Organization for Standardization, 2010).

**Diamond abrasive blade**

The diamond abrasive blade that is used with a masonry saw is a metal disk. Its cutting area is either continuous or segmented and set with industrial diamond crystals. Blades must comply with the ABNT NBR 15910:2010 set of specifications (Brazilian Association of Technical Standards, 2010): 12,000–14,000 rpm rotation; 110–125 mm diameter; 20 mm central bore; 1.4–1.6 mm thickness; 6–8 mm diamond height; 1.8–2.2 mm diamond thickness.

**International standard sound power level measurement**

The international standard ISO 3744:2010 (Brazilian Association of Technical Standards, 2010) is part of the ISO 3740 series of standards for assessing sound power levels. It specifies methods of measuring sound pressure levels on a surface enveloping the noise source in an environment that approximates an acoustic free field over a reflecting plane. This standard aims to achieve standardized determination of sound power and energy levels from noise sources, such as machinery, equipment, and their sub-assemblies. The specified methodology requires assessment in the open air or a wide environment which reflects energy not significantly influence the energy radiated by the source.

**MATERIALS AND METHODS**

This study aims to develop a methodology compatible with the international standard for studying the levels of noise generated outdoors by masonry saws, considering the large amounts of dust generated when they cut materials. ISO 3744:2010 states that testing environments should be close to normal operating conditions to ensure the relevance of results. The measurement is conducted as stipulated by the standard; specific cutting conditions (that is, a standard material to be cut) are proposed to allow the standardized assessment of masonry saws under conditions closely resembling those found during their regular use. To achieve an authentic simulation of regular use, the tests of this study were conducted while the trained builders operated the masonry saws.

**Operations with masonry saws**

Masonry saws were used to perform common cutting tasks. The saws and diamond blades were new for the task, in
accordance with current standards. The brands and models were readily commercially available and are often used at construction sites. Measurements were performed in an open area of a university campus; the floor was unpaved with some areas of trimmed grass; the surroundings were flat without sources of constructive interference and with low external noise.

Reflecting plane

ISO 3744:2010 stipulates a reflecting plane to have an absorption coefficient of less than 0.1 for the frequencies of interest. Fibers board with medium density wood - MDF (Medium Density Fiberboard) was used here; it was a material with smooth coated high gloss veneer with a thickness of 20 mm. The dimensions of the flat reflector exceeded 0.5 m on each side of the measurement surface as normative determination. The choice of MDF as flat reflector gave up because it is a rigid material and plan with adequate absorption coefficient at the frequencies of interest. The dimensions of the used MDF plane were 3.45 × 3.45 m (area 11.9025 m²; Figures 1 and 2c).

Measurements and materials

Sound pressure levels of background noise were measured and compared with those of masonry saws running freely and while cutting cement slabs (the proposed standard load), ceramic plates, and slate. To ensure greater reproducibility of the assay, two types of standardized flat concrete slab were prepared based on the characteristics of the materials used in the pre-test (International Organization for Standardization, 2010). The cement slabs (dimensions 0.40 × 0.40 m, thickness 2 or 4 cm) were fabricated by a technician using a specific composition of mortar made using a 1:2:0.45 volume ratio of portland cement type II (moderate sulfate resistance), aggregate quartz sand with a specific gravity of 2.58 g cm⁻³, and treated water. The ceramic plates (model A5-3011, hue 210, classification/lot B27, dimension 0.31 × 0.31 m, thickness 0.75 cm) were from a manufacturer that is regularly accredited by the Brazilian Association of Ceramic Tile Manufacturers. They were red flooring tiles from a widely available and popular commercial brand; all the tiles were from the same manufacturing batch. The tiles complied with the international standard for the classification of ceramic tiles (ISO 13006) and also the Brazilian standard for the specification and testing of ceramic tiles (ABNT NBR 13818) (Brazilian Association of Technical Standards, 2003). The slate plates (dimension 0.40 × 0.40 m, thickness 0.70 cm) were from the same production lot; they complied with Brazilian standard ABNT NBR 15012:2003 (Brazilian Association of Technical Standards, 1997). The slate was of low commercial value; it is regarded as semi-ornamental and is widely used in construction, both commercial and residential.

Equipment and measurement times

Noise was measured using a sound level meter (Brüel and Kjær, model 2260). Sound pressure levels were measured with respect to frequency in 1/3 octave bands between 100 and 10,000 Hz. Each measurement was for 10 s, in accordance with ISO 3744:2010.

Measurement arrangement

According to ISO 3744:2010, the condition of the radiation field and the minimum dimensions of the test environment must be arranged such that the measurement points can be described as occupying certain points on the faces of a cuboid-shaped measurement surface. Figure 1 shows the measurement points and their physical arrangement.

The hatched area in Figure 1 denotes the plane reflector; the central shaded box represents the noise source located under a reflecting plane. The standard states that six measurements must be performed during each operation of the machine \(L_{p(\text{Band})}\) at each point in the measurement surface.

Figure 2(a) shows the masonry saw used. Figure 2(b) depicts its cutting marble in an open field on a plane reflector. Figure 2(c) shows the projection of the measurements surface.

Calculation of sound pressure levels

The sound pressure levels from the measurements were determined as follows:

\[
L_{\text{p(ST)}} = 10 \log \left[ \frac{1}{N_M} \sum_{i=1}^{N_M} 10^{0.1L_{p(ST)}} \right] \text{ dB} ,
\]

where \(L_{p(ST)}\) is the mean frequency-band sound pressure level in decibels (dB) measured from the positions in the measurement surface test (ST), and \(N_M\) is the number of microphone positions used in the measurement surface.

The mean sound pressure level of the background noise \(L_{p(B)}\) shall be calculated using equation:

\[
L_{p(B)} = 10 \log \left[ \frac{1}{N_M} \sum_{i=1}^{N_M} 10^{0.1L_{p(B)}} \right] \text{ dB}
\]

where \(L_{p(B)}\) is the time-averaged sound pressure level of the background noise measured at the \(i\)th microphone.
position, or $i$th microphone traverse, in decibels, and $N_m$ is
the number of microphone positions or individual
microphone traverses.

The surface time-averaged sound pressure level, $L_p^{(ST)}$, shall be calculated by correcting the mean time-averaged sound pressure level, $L_p^{(ST)}$, for background noise ($K_1$) and for the influence of the test environment ($K_2$) using Equation (3):

$$L_p = L_p^{(ST)} - K_1 - K_2$$  

(3)

The background noise correction, $K_1$, shall be calculated using Equation (4):

$$K_1 = -10 \log \left( 1 - 10^{-0.1 \Delta L_p} \right) \text{dB}$$  

(4)

where:

$$\Delta L_p = L_p^{(ST)} - L_p^{(B)}$$  

(5)

According to ISO 3744:2010, in external areas, on rigid surfaces, with no obstacle preventing reflection to the surroundings and at a distance equivalent to 10 times the greatest distance between the source and the end of the measuring surface, the correction due to the environment $K_2$ can be disregarded. Thus, for the environmental conditions used in the study, the coefficient $K_2=0$ was adopted.

**Calculation of uncertainty measurements**

According to ISO 3744:2010, from the estimated total standard deviation $\sigma_{tot}$, the measurement uncertainty was determined as follows:

$$u(L_{ref, atm}) = \sigma_{tot} = \sqrt{\sigma_{R_0}^2 + \sigma_{omc}^2} = \sqrt{\sum_i (c_i u_i)^2 + \sigma_{omc}^2}$$  

(6)

where:
\[ \sigma_{\text{tot}}: \text{estimated total standard deviation}; \]
\[ \sigma_{\text{omc}}: \text{deviation from uncertainties, instability of operation and assembly conditions}; \]
\[ \sigma_{\text{R0}}: \text{deviation corrected for environmental uncertainties and test conditions}; \]
\[ C_i: \text{sensitivity coefficient of the } i\text{-th component of the deviation } \sigma_{\text{R0}}; \]
\[ u_i: \text{standard uncertainty of the } i\text{-th component of the deviation } \sigma_{\text{R0}}. \]

The measurement uncertainty used in ISO 3744:2010 is determined by the expanded measurement uncertainty \( U \), which is derived directly from the total standard deviation \( \sigma_{\text{tot}} \), being the approximation of the relevant \( u(L_W) \) as defined in the ISO/IEC Guide 98-3. This total standard deviation, \( \sigma_{\text{tot}} \), results from the two components \( \sigma_{\text{omc}} \) and \( \sigma_{\text{R0}} \).

The calculation of the standard deviation \( \sigma_{\text{omc}} \) is obtained by the equation:

\[
\sigma_{\text{omc}} = \sqrt{\frac{1}{N - 1} \sum_{j=1}^{N} (L_{p,j} - L_{pav})^2} \text{ dB} \tag{7}
\]

where:
\[ L_{p,j}: \text{the sound pressure level measured at a prescribed position and corrected for background noise for the } j\text{-th repetition of the prescribed operating and mounting conditions}; \]
\[ L_{pav}: \text{its arithmetic mean level calculated for all these repetitions}. \]

Derived from \( \sigma_{\text{tot}} \), calculate the expanded measurement uncertainty \( U \), in decibels:

\[
U = k \cdot \sigma_{\text{tot}} \tag{8}
\]

The uncertainty of measurement depends on the degree of confidence desired. ISO 3744:2010 recommends that for a normal distribution of measurement values there is 95\% confidence that the true value will lie within a range corresponding to a range factor of \( k = 2 \).

According to ISO 3744:2010, the uncertainties components measurement of the environmental conditions and test, \( \sigma_{\text{R0}} \) are detailed in Table 1, which presents the considered value or corresponding formula of the variables of standard uncertainty, probability distribution, estimated value and coefficient of sensitivity of each associated parameter, besides the normative representation of the component.

The degree of dispersion of the numerical parameters obtained in this study is calculated using the standard deviation as follows:

\[
\sigma = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (X_i - \bar{X})^2} \tag{9}
\]

where:
\[ X_i: \text{levels obtained in measurements}; \]
\[ \bar{X}: \text{average level of the sample}; \]
\[ n: \text{number of measurements taken in the sample}. \]

**Cause-effect diagrams on measurement uncertainties**

The sound pressure levels from the measurements were determined as follows. The cause–effect diagrams of Figures 3 and 4 show the sources of uncertainties and the magnitudes associated with the instability of the operation, environmental conditions, assembly and tests in the determination of the sound levels of a portable saw for an essentially free plane. These diagrams illustrate the sources of uncertainties identified and the input quantities that define the uncertainty of the respective parameters \( \sigma_{\text{omc}} \) and \( \sigma_{\text{R0}} \) during the trials conducted in this research. They are provided to better visualize all the associated parameters in the results of the uncertainty parameter.

**RESULTS AND DISCUSSION**

Tables 2, 3, 4, 5 and 6 show the results of the standard uncertainty \( u \) and coefficient of sensitivity \( c \) of the parameters associated with the conditions and test situations, method, microphones and instrumentation, temperature, relative humidity, angle and test constants in accordance with ISO 3744:2010.

Also presented are the results of the uncertainties of the instability of the operation and conditions of assembly \( \sigma_{\text{omc}} \), of the uncertainty deviations of the environmental and test conditions \( \sigma_{\text{R0}} \), total deviation \( \sigma_{\text{tot}} \), range factor \( k \) and the expanded measurement uncertainty \( U \) at different load conditions of the masonry saw operated in an open field on a reflecting plane.

The calculations performed illustrate the uncertainties of measurement at all frequencies, at the different conditions of loading of the marble saw in the operations, and also presenting the corresponding total uncertainty. It is observed that the greatest contribution to the measurement uncertainty in the total deviation \( \sigma_{\text{tot}} \) is related to the uncertainty of the environmental and test conditions \( \sigma_{\text{R0}} \), denoting the importance of meeting the normative requirements in relation to assembly, dimensions, instrumentation, environment and their test constants.

The uncertainty regarding the instability of the operation and the conditions of assembly \( \sigma_{\text{omc}} \) is low and is very similar for all frequencies and in all the load conditions, making it clear that the sound levels obtained in the realized
Table 1: Uncertainty budget for determinations of $\sigma_{RO}$.

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Estimate $^a$ dB</th>
<th>Standard uncertainty $^a$, $u_i$ dB</th>
<th>Probability distribution</th>
<th>Sensitivity coefficient $^a$, $c_i$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta L_{eq}$, method</td>
<td>0</td>
<td>0,4</td>
<td>Normal</td>
<td>1</td>
</tr>
<tr>
<td>$L_{eq}^{ST}$, mean time-averaged sound pressure level</td>
<td>$\frac{L_{eq}^{ST}}{S_0}$</td>
<td>$s_{L_{eq}^{ST}}/\sqrt{n}$</td>
<td>Normal</td>
<td>$1 + \frac{1}{10^{0.1\Delta/M_{R}-1}}$</td>
</tr>
<tr>
<td>$S$,          measurement surface area</td>
<td>$10 \log \frac{S}{S_0}$</td>
<td>$\Delta r/\sqrt{S}$</td>
<td>Rectangular</td>
<td>8,7$\sqrt{r}$</td>
</tr>
<tr>
<td>$K_1$,         background noise correction</td>
<td>$K_1$</td>
<td>$s_{L_{eq}(B)}$</td>
<td>Normal</td>
<td>$\frac{1}{10^{0.1\Delta/M_{R}-1}}$</td>
</tr>
<tr>
<td>$K_2$,         environmental correction</td>
<td>$K_2$</td>
<td>$K_2/4$</td>
<td>Normal</td>
<td>1</td>
</tr>
<tr>
<td>$C_1 + C_2$, meteorological and radiation impedance corrections</td>
<td>$C_1 + C_2$</td>
<td>0,3</td>
<td>Triangular</td>
<td>1</td>
</tr>
<tr>
<td>$\delta S_{pr}$, sound level meter</td>
<td>0</td>
<td>0,5</td>
<td>Normal</td>
<td>1</td>
</tr>
<tr>
<td>$\delta S_{sr}$, sampling</td>
<td>0</td>
<td>$V_1/\sqrt{S}$</td>
<td>Normal</td>
<td>1</td>
</tr>
<tr>
<td>$\delta S_{sa}$, angle</td>
<td>0</td>
<td>Box: 0,05 + 0,6lg(S / $d^2$)</td>
<td>Rectangular</td>
<td>$10^{-K_{2}/10}$</td>
</tr>
<tr>
<td>$\delta S_{sd}$, Hemisphere</td>
<td>0</td>
<td>0,25</td>
<td>Normal</td>
<td>0,0011 / $T$ + 0,007$F$</td>
</tr>
<tr>
<td>$\delta S_{sp}$, temperature</td>
<td>0</td>
<td>$\Delta T/\sqrt{S}$</td>
<td>Rectangular</td>
<td>$-0,57 + 0,25lg(2,6T)$ (1 - $10^{-K_2/10}$)</td>
</tr>
<tr>
<td>$\delta S_{sh}$, relative humidity</td>
<td>0</td>
<td>$\Delta H/\sqrt{S}$</td>
<td>Rectangular</td>
<td>$-2,6 + 1,6lg(0,7T)$ (1 - $10^{-K_2/10}$)</td>
</tr>
</tbody>
</table>

$^a$ Quantities are described in the numerical example following this table.


Figure 3: Measurement arrangement - $\sigma_{RO}$ parameters.
measurements represent in a reliable way the operation of the portable saw, according to the method adopted during this study of the sound levels generated in a free field on a reflecting plane. In most frequencies, the greatest contribution to the uncertainty is related to the uncertainty of the sound pressure level $u L_p^{[ST]}$, which refers to the repeatability of measurement, this being larger at low frequencies, possibly influenced by background noise and the vibration behaviour of the portable saw and cutting materials. The uncertainty regarding the measuring surface is zero, since there is no variation in this parameter during measurements.

The uncertainty regarding the background noise $K_1$ is present only in the frequency bands that needed to be corrected in this parameter, while the uncertainty regarding the environmental correction $K_2$ is zero, since this correction was disregarded according to the prerogative of the ISO 3744:2010. Likewise, the uncertainty components
concerning temperature $\delta_\theta$ and relative humidity $\delta_H$, where $K_2$ is the coefficient of sensitivity in the calculations, resulting in a value equal to zero for these parameters.

The expanded measurement uncertainty ($U$) with respect to frequency, resulting from all the magnitudes associated with the operations of the portable saw in the sound level measurement tests, under different load conditions in an open field on the reflecting plane, is represented in Figure 5.
Table 5: Masonry saw measurement uncertainties: cutting 4cm-thick standard load.

<table>
<thead>
<tr>
<th>( f ) [Hz]</th>
<th>( \Delta L ) [mm]</th>
<th>( \delta_{\text{mean}} )</th>
<th>( S )</th>
<th>( K_1 )</th>
<th>( K_2 )</th>
<th>( C_1 + C_2 )</th>
<th>( \delta_{\text{unc}} )</th>
<th>( \delta_{\text{appro}} )</th>
<th>( \delta_y )</th>
<th>( \delta_g )</th>
<th>( \sigma_{\text{U}} )</th>
<th>( \sigma_{\text{unc}} )</th>
<th>( \sigma_{\text{tol}} )</th>
<th>( U )</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>4.4</td>
<td>0.0</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.3</td>
<td>1.0</td>
<td>0.2</td>
<td>1.0</td>
<td>0.1</td>
<td>0.1</td>
<td>0.7</td>
<td>1.0</td>
</tr>
<tr>
<td>125</td>
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<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.3</td>
<td>1.0</td>
<td>0.2</td>
<td>1.0</td>
<td>0.1</td>
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<td>0.7</td>
<td>1.0</td>
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<tr>
<td>150</td>
<td>1.2</td>
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<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.3</td>
<td>1.0</td>
<td>0.2</td>
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<td>0.1</td>
<td>0.1</td>
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<tr>
<td>200</td>
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<tr>
<td>300</td>
<td>0.0</td>
<td>0.0</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
<td>0.3</td>
<td>1.0</td>
<td>0.2</td>
<td>1.0</td>
<td>0.1</td>
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<td>400</td>
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<td>0.0</td>
<td>0.4</td>
<td>0.0</td>
<td>0.0</td>
<td>0.1</td>
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<td>500</td>
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<td>0.4</td>
<td>0.0</td>
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<td>800</td>
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<td>0.1</td>
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<td>1.0</td>
<td>0.1</td>
<td>0.1</td>
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Table 6: Masonry saw measurement uncertainties: cutting 4 cm-thick standard load.

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<thead>
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<th>( f ) [Hz]</th>
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<td>0.1</td>
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<td>0.7</td>
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Also presented are the mean expanded measurement uncertainty and the standard deviation. It is observed that the largest values of the expanded measurement uncertainty (U) are present at the low frequencies. It is possible to notice that the uncertainty in the unloaded condition has similar behaviour in relation to...
the cutting operations with the different materials. There is a proximity in the uncertainty values for all load conditions from 1 to 10 KHz, indicating the reliability of the results in this frequency range by the method adopted. A constant standard deviation of the order of 0.1 dB is observed at frequencies above 500 Hz. Note that the mean of the expanded uncertainty measurement (U) in the different load conditions is very similar, which is possibly associated with the significant contribution of the uncertainty of the environmental and test conditions ($\sigma_{R0}$).

Based on these results, it can be inferred that the value of $U = 4.3$ dB reliably represents the expanded measurement uncertainty (U) in portable saw operations cutting materials. Considering the interpretative analysis of the test conditions of ISO 3744:2010, the method adopted in this study is associated with a degree of precision 2 (in relation to the standard deviation of reproducibility) and can be considered as unstable in relation to the conditions of assembly and operation.

**CONCLUSIONS**

The contribution of the uncertainty is related to the environmental and test conditions associated with the repeatability of the measurements of the sound pressure level generated in the operations. Parameters related to the instability of the operation and the assembly conditions are low, revealing that the use of the portable saw, blades, load-bearing support, the reflective plane, cutting materials and the operator, have reliably represented the levels of sound pressure generated by the portable saw in the different cutting conditions.

Calculations of the standard deviations associated with the instability of the operation, assembly conditions, environmental and test conditions aggregate at a normal range factor of 2, which corresponds to 95% confidence that the true value is within the range used, showing that the expanded measurement uncertainty (U) to be considered in a sound power method generated by a free-range portable saw on a reflecting plane, according to ISO 3744:2010, is $U = 4.3$ dB.

As proposals for future work, the following is suggested: relating the physical characteristics of the materials with the cutting noise generated; proposing an automated device to replace the operator with particular sensitivity in handling of the saw; study of the vibration behaviour of plates, resonance frequencies, harmonics series generated and their interference with the generated noise; investigation of the sound power by acoustic intensimetry; a study of machines and different types of diamond blades and their relationships with the noise generated.

This study contributes to the analysis of the uncertainty of measurements of sound levels of portable tools operating on materials in the quest to contribute to improvements in the tests of noise pollution from industry.

**REFERENCES**


